NORTH CAROLINA
DEPARTMENT OF CONSERVATION AND DEVELOPMENT
R. BRUCE ETHERIDGE, DIRECTOR

DIVISION OF MINERAL RESOURCES
JASPER L. STUCKEY, STATE GEOLOGIST

BULLETIN NUMBER 56

TALC DEPOSITS OF THE MURPHY MARBLE BELT

BY
EARL C. VAN HORN

PREPARED AND PUBLISHED IN COOPERATION WITH THE TENNESSEE VALLEY AUTHORITY
UNDER THE DIRECTION OF
JASPER L. STUCKEY, NORTH CAROLINA DEPARTMENT OF CONSERVATION AND DEVELOPMENT
AND
H. S. RANKIN, TENNESSEE VALLEY AUTHORITY

RALEIGH
1948

North Carolina
Department of Conservation and Development
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MEMBERS OF THE BOARD OF CONSERVATION AND DEVELOPMENT

LETTER OF TRANSMITTAL

Raleigh, North Carolina
November 22, 1948

To His Excellency, HON. R. GREGG CHERRY,
Governor of North Carolina.

SIR:

I have the honor to submit herewith manuscript for publication as Bulletin 56, "Talc Deposits of the Murphy Marble Belt." This bulletin is another in the series being made possible by the cooperation of the Tennessee Valley Authority.

The Murphy Marble Belt has produced varying amounts of high grade talc for more than 85 years. Although geological work has been done in the area at different times, this bulletin represents the first detailed geological report covering, as a unit, that part of the Murphy Marble Belt lying within the State of North Carolina. This report indicates that there are ample reserves of talc in the area for long term operations, and it is believed that the information contained herein will be of value to those interested in the area.

Respectfully submitted,

R. BRUCE ETHERIDGE,
Director.

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TALC DEPOSITS OF THE MURPHY MARBLE BELT

By Earl C. Van Horn

ABSTRACT

The Murphy marble belt extends some 35 miles in North Carolina from Wesser to the Georgia state line, including parts of Swain, Macon, and Cherokee Counties. Talc mining in the area is more than three-quarters of a century old and has persisted in spite of many difficulties. However, in recent years most of the mines and prospects have been abandoned and the utilization of talc resources has been at a minimum.

The purpose of the current work was to find geologic criteria and establish methods for locating concealed talc and generally to sponsor and assist in the development of old and new talc resources and to acquire and apply new scientific and economic data.

The Murphy marble formation, which is the only host formation to commercial talc in the area, is a true marble of nonuniform mineralogy, exposed as a part of the northwest limb of an overturned anticline. It is believed that the Murphy marble is conformable with adjacent rocks which comprise a series of schists, gneisses, and quartzites having distinct variations both along and across the strike and which are probably of pre-Cambrian (?) Ocoee age.

In addition to a revision of previous theories concerning the attitude of the Murphy marble, new data are presented concerning structural variations within the marble, and the marble formation has been subdivided into lithologic units. Relationships between the marble and its contained talc deposits have been clarified to the extent of delimiting occurrences of commercial talc to a specific zone of the marble formation. It has been established that the attitudes of talc bodies are controlled by the attitudes of intraformational folds and are reflected in lineation phenomena. Theories are advanced to account for elliptical shapes of talc bodies.

The mineralogy of the talc is discussed. It is proposed that the talc was formed by the actions of hydrothermal solutions rising from a granitic or dioritic magma, first silicifying a dolomitic rock and later effecting a replacement by talc without an intermediate chlorite or amphibole phase. It is further proposed that mineralizing solutions were given access by real or incipient weaknesses which were formed because of an original dolomitic character of the central part of the marble.

A geologic map of the marble belt and adjacent formations accompanies this report. A total of two operating mines and 39 prospects and abandoned mines are described in the text and marked on the geologic map. Results of diamond core drilling are described and correlated, and recommendations for future exploration work are presented.

INTRODUCTION

Talc deposits in western North Carolina occur in two settings. Deposits having the widest distribution are associated with basic igneous rocks, particularly the olivine-bearing varieties in Macon and Jackson Counties and pyroxene-bearing varieties in Madison County, but talc of this type has received little serious attention in the past. Of much greater importance are the deposits that occur as lenses and beds in very old dolomitic marbles in the counties of Swain, Macon, and Cherokee. This report is concerned only with the last named three counties.

PURPOSE OF INVESTIGATION

The North Carolina Department of Conservation and Development and the Regional Products Research Division of the Commerce Department of TVA established a cooperative program as a basis for this investigation of the talc resources in the Murphy marble belt of the tri-county area. Specific purposes of the investigation were: (1) to develop criteria and methods for determining accurately the location of concealed talc deposits; (2) to locate new talc reserves; (3) to assist property owners, investors, and operators in attaining higher efficiency in the exploration and development of deposits; and (4) to acquire and sponsor the application of geologic and economic information that has not been available heretofore.

FIELD WORK AND ACKNOWLEDGMENTS

All work was under the general direction of Mr. H. S. Rankin, Head, Minerals Research Section, Commerce Department, TVA, and Dr. J. L. Stuckey, State Geologist, North Carolina Department of Conservation and Development. Mr. E. L. Miller, Jr., of the North Carolina Department of Conservation and Development, was in the field during the summer of 1945, working principally in the vicinity of the Nantahala River and in the talc mines at Murphy, North Carolina. Mr. M. K. Banks, of TVA, assisted the writer from October 1945 to June 1946, and contributed especially to an understanding of the Nottely quartzite and the diorite sills. Dr. W. A. White, of the North Carolina Department of Conservation and Development, did petrographic work in the field during the summer of 1946. Any success resulting from this program would not have been possible without the splendid cooperation of all talc producers, owners, and mine personnel in the area. Special acknowledgment is due Messrs. J. W. Bailey, Jr., J. W. Bailey, Sr., F. C. Bourne, P. B. Ferebee, W. B. Hartsfield, and Jesse Ledford. The TVA Maps and Surveys Division prepared most of the plates and figures contained herein. Messrs. Benjamin Gildersleeve and B. C. Moneymaker, of the TVA, have kindly reviewed these writings, and the writer is grateful to Mr. C. E. Hunter, TVA, Dr. Jasper L. Stuckey, North Carolina State Geologist, and especially to Mr. Thomas L. Kessler, Geologist, Cartersville, Georgia, for their critical reading of the manuscript. The writer was in charge of this investigation from its inception in June 1945 to its completion in March 1947, and has performed most of the work. While the ideas contained herein are certainly not all his own, the writer assumes full responsibility for the information presented. Approximately half of the field work was spent in working with talc owners, operators, and investors. The remaining work was devoted to areal geology, mine mapping, drill core studies, detailed study of talc occurrences, and related research.

GEOGRAPHY

In North Carolina the Murphy marble belt extends some 35 miles from near Wesser, Swain County, southwestward across the northwest tip of Macon County, through Topton, Andrews, Marble, and Murphy in Cherokee County, to the state line. From the state line the marble has been observed southward in Georgia for nearly 50 miles to the vicinity of Canton, Georgia. Unless otherwise specified, subsequent discussion of the marble belt will refer only to that portion within North Carolina.

PHYSIOGRAPHY

The physiography of the area has not been worked out in detail, but in general it is characterized by inter-related low order straths. With few exceptions, stream valleys occupy, or are adjacent to, the marble belt. From the northeastern terminus near Wesser to the vicinity of Topton, the marble is exposed in the gorge of the Nantahala River, with numerous outcrops high on the northwest side of the gorge at elevations 3,500 feet above sea level, or 600 feet above the river bed. From Topton southwestward to Murphy, the marble usually underlies the lowlands formed by the Valley River. From Murphy, the marble crosses a small divide between the Nottely and Hiwassee Rivers, underlies the Nottely River to near Ranger, and then is traced by small creeks throughout the remainder of its extent. Thus, general drainage patterns are controlled by the marble formation, but in detail the marble often is outside stream valleys, trending along adjacent slopes and across low divides.

Keith[1] says the Nantahala River originally flowed down the Cheoah Valley along what is now Tulula Creek and was diverted by a branch of the Little Tennessee River working back along the Murphy marble. It appears equally possible that the Nantahala once flowed westward, through Red Marble Gap and down the present course of the Valley River. Large, well-rounded boulders of quartzite and vein quartz and smaller fragments of rocks typical of the upper reaches of the Nantahala River may be found along this course, which is coincident with the marble formation.

[1] Arthur Keith, U. S. Geol. Survey Atlas, Nantahala folio (no. 143), 1907, p. 1.

TRANSPORTATION AND POWER

Nearly all of the marble belt is situated satisfactorily with respect to transportation facilities. The Murphy branch of the Southern Railroad follows the belt from Wesser to Murphy, and U. S. Highway 19 is seldom more than a few hundred yards from the marble over the same distance. To the west from Murphy, a branch of the Louisville and Nashville Railroad parallels the marble, as do several good state highways and county roads. Only between Ranger and Culberson is access to the marble formation at all difficult. Additional facilities are available as a result of the large number of conveniently spaced railroad sidings which are used for loading pulpwood along the two railroads.

Electric power is readily available throughout the length of the marble belt. Between Culberson and Marble, TVA power is supplied by the cooperatives at Murphy and at Blue Ridge, Georgia. The Nantahala Power and Light Company provides electricity in all localities between Marble and Hewitt.

HISTORY OF THE TALC INDUSTRY

Talc mining was begun in the Murphy marble belt in 1859[1] and has persisted in spite of many economic difficulties. There were no railroads in the area in those early days and the industry continued only so long as high prices justified the use of horse-and-wagon transportation. New sources of talc soon forced prices down to a level at which operations in North Carolina were no longer profitable, and mining was halted until the railroads entered the region in the late 1880's.

As interest was revived, land owners and prospectors became familiar with those places where talc could be seen at the surface. Prospect pits and trenches were dug, abandoned, and reopened time and again. It appears that, from 1898 to 1928, only four or five talc "mines" were worthy of the name. These were: (1) the Hewitt Mine, near Hewitt Station on the Nantahala River, (2) the Valleytown Mineral Company mine, later the Biltmore Talc Company, two miles east of Tomotla, (3) the Hayes Mine at Tomotla, (4) the Hillyer Mine, about one mile east of Kinsey, and (5) the Kinsey Mine at Kinsey (Map Location No. 5). In addition, almost the entire southeast slope of Talc Mountain at Hewitt was trenched and tunneled ("gopher-holed") for talc, with fairly successful results. The main production of talc was supplemented with small quantities of talc brought in by prospectors and sold in 100-pound lots to the larger producers. In 1927, the Notla Talc Company began an exploration program and developed the Carolina Talc Company mine just east of Kinsey. Production was begun in 1930, and, because of various peculiar conditions, the mine was closed in 1938 after a highly successful period of operation.

In recent years most mines and prospects have been abandoned, and results of the search for larger and better talc deposits have been discouraging. The talc industry in western North Carolina did not flourish because of the following conditions:

1. Many prospects have been located at sites having adverse surface and underground drainage and unfavorable bedrock conditions. Prospects have been opened on the banks and in the beds of streams because these are ideal places for talc to crop out and be seen easily. Many prospects and some mines (*cf.* Map Locations Nos. 17 and 18) were located in talc float which was from 10 to 100 feet from its source. It is not rare that much useless digging has been done because of the presence of a few talc scales (or, less rarely, sericite and chlorite scales) in the first few inches of top soil.

2. Low, uncertain production has not been conducive to the use of suitable mining equipment. Probably the chief cause of mine and prospect abandonment, where conditions otherwise were suitable, has been a lack of pumps, because many operations were begun "on a shoestring" and investment in adequate pumping equipment was rare. Similarly, hard rock has caused many prospects to be abandoned because of a lack of proper drilling equipment. Ordinarily, if simple pick and shovel work could not produce enough talc to pay its way, prospects never reached the proportions of mines.

3. Owners and mine operators have not obtained suitable technological assistance, and their methods have been slow, costly, and relatively inffective. Plans of operation and theories of talc occurrence have

[1] J. H. Pratt, Talc and Pyrophyllite Deposits in North Carolina, North Carolina Geol. and Econ. Survey, Econ. Paper, no. 3, 1900, p. 8.

depended on legends and hunches, and core drilling has not been popular because of high unit cost and the failure to utilize information which could have been obtained from "dry" holes. Mine shafts have been poorly designed, and drifts and crosscuts were either too small in barren ground or too large where talc was encountered.

It is apparent that the search for talc deposits heretofore has been fortuitous and unsystematic. Only since 1942 has there been a change in the general philosophy of exploring for concealed talc deposits. This is discussed further in the section on descriptions of the deposits.

PREVIOUS GEOLOGIC WORK

AREAL GEOLOGIC MAPPING

The geology of the area which includes the Murphy marble belt has been worked out previously only by Keith in the published Nantahala folio[1], and in an unpublished folio on the Murphy quadrangle. In spite of the short time that Keith worked in this large area of complex geology and rugged topography, his lithologic descriptions can be improved only through elaboration.

In the immediate vicinity of the marble belt, Keith differentiated nine separate formations, designated as of Cambrian age, which he believed to occur in a major syncline. His oldest formation in the group was the Hiwassee slate, a dark, banded, micaceous slate having a thickness of more than 500 feet. He mapped the Hiwassee slate only on the northwest side of his synclinical axis. The Great Smoky formation was shown as more than 6,000 feet of clastics which included conglomerate, sandstone, "graywacke", black slates, and quartz-, mica-, kyanite-, garnet-, and staurolite schists and gneisses. The Nantahala slate was mapped as nearly 2,000 feet of black slates and kyanite-, staurolite-, and garnet schists. The Tusquitee quartzite was described as from 20 to 500 feet of dense white quartzite. The Brasstown formation consisted of about 1,000 feet of dark gray or black ottrelite schist and slate, and lighter-colored mica schist. The Valleytown formation was mapped as 1,000 feet of garnet schist, "graywacke", ottrelite schist, and slate. The Murphy marble was shown as pure limestone and dolomite ranging in thickness from 150 to 500 feet. Immediately on either side of the synclinal axis Keith mapped the Andrews schist, comprising 200 to 500 feet of calcareous ottrelite schist and limonite beds. The central part of Keith's syncline, and youngest formation of the series, was the Nottely quartzite, mapped as about 150 feet of white quartzite. Excepting the Hiwassee slate and the Murphy marble, all formations were shown as being repeated on each side of the synclinal axis. The missing limb of the Murphy marble was explained by a major thrust fault which has since been known as the Murphy Fault. The occurrences of marble southeast of the Murphy Fault were mapped as fault outliers.

To the southeast of the series described above, Keith mapped the Archean Carolina gneiss, a complex of schists, gneisses, and granitoid layers, characterized in that area by intricate crumpling and folding.

WORK RELATED TO THE TALC DEPOSITS

Pratt[2] made a general study of the talc deposits of the belt in 1899. His opportunities for seeing the talc in place were rather limited, and his conclusions apparently were influenced by the testimony of mine workers and by the examination of unsatisfactory exposures; for instance, he confused the Nottely quartzite with siliceous phases of the Murphy marble. Several years later, Arthur Keith studied talc occurrences[3] in connection with his geologic mapping in the southern Appalachians. He interpreted the geology of the talc in greater detail than did Pratt, but did not have sufficient time in the field to obtain a clear picture of the many problems involved.

Studies of associated brown iron ores by Bayley[4], and of associated limestones by Loughlin, Berry, and Cushman[5] have contributed indirectly to a knowledge of the talc deposits, chiefly through observations of

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[1] Arthur Keith, 1907.
[2] J. H. Pratt, 1900.
[3] Arthur Keith, Talc Deposits of North Carolina, U. S. Geol. Survey Bull. 213, 1903.
__________, U. S. Geol. Survey Atlas, Nantahala folio (no. 143), 1907.
[4] W. S. Bayley, Deposits of Brown Iron Ores in Western North Carolina, North Carolina Geol. and Econ. Survey, Bull. 31, 1925.
[5] G. F. Loughlin, E. W. Berry, and J. H. Cushman, Limestones and Marls of North Carolina, North Carolina Geol. and Econ. Survey, Bull. 28, 1921.

lithology and mineralogy in adjacent formations. More direct and important knowledge of the talc was supplied by Stuckey, who, in following up his work on pyrophyllite in North Carolina, made petrographic studies of the Murphy talc but did not include detailed surveys of the various deposits[1]. Gillson[2] and Moneymaker[3] contributed ideas on the origin of the Murphy talc on the basis of published reports of field work by Pratt, Keith, and Stuckey.

MAJOR PROBLEMS

Results of the present work indicate that Keith's interpretation of structural and age relations of the rocks of the Murphy marble belt are erroneous, at least in part. To increase the complexity of the problems involved in this investigation, work subsequent to Keith's has been based on his geologic time scale, and errors, therefore, have been accumulative. Although the work which is reported in the present discussion has been restricted to a small part of the area involved and is not of a nature to solve the many general problems, it is believed that the results obtained will contribute to a more accurate understanding of the areal geology.

In their work on the geology of the Appalachian region, G. W. and Anna J. Stose have taken a broader view of the problems at hand. Expanding on their own work, and on the work of Safford, Hayes, and Crickmay[4], as well as of Keith[5], the Stoses have established a currently accepted theory that the series from the Hiwassee slates through the Valleytown formation are of pre-Cambrian (?) age and may be identified as Ocoee series. They conceded the possibility that Keith's Nottely quartzite, Andrews schist, and Murphy marble might be of Lower Cambrian age, but suggested that the Nottely quartzite is the oldest and the Murphy marble the youngest of the three formations, and that the iron-bearing Andrews schist may be transitional between the quartzite and the marble. Also, they suggested that this trio may represent a window exposed in the Great Smoky overthrust block (Ocoee age)[6].

In general, the age relationship of the rocks of the area would be of little consequence insofar as the economics of the talc deposits are concerned, but, as will be seen later in discussions of lithologic phases and of the location of talc deposits within the marble formation, a basic concept is in need of clarification since the three dimensional position of the marble, and consequently of the talc deposits, is involved. It is important to solve the question of the presence or absence of one or more major stratigraphic faults, as well as the type of major folding, whether synclinical or anticlinal, since these problems have a direct bearing on the occurrence and position of concealed talc bodies. The resolution and/or revision of all these theories will guide future geologic work in the area and assist in developing more accurate methods of prospecting for mineral resources.

LITHOLOGIC UNITS

A full understanding of the marble formation and its contained talc requires a rather precise picture of the formations immediately adjacent to the marble, and a somewhat broader view of the over-all series of rocks of the area. Areal geologic mapping was carried out accordingly, with detailed work in the central portion of the belt, and more general studies in the outer areas. In the more rugged country, the scope of this program did not permit thorough survey work, and Keith's mapping was depended upon to some extent.

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[1] J. L. Stuckey, Pyrophyllite Deposits of North Carolina, North Carolina Dept. Cons. and Dev. Bull. 37, 1928.
________, Talc Deposits of North Carolina, Econ. Geology, vol. 32, no. 8, pp. 1009-1018, 1937.

[2] J. L. Gillson, Origin of the Vermont Talc Deposits, Econ. Geology, vol. 22, pp. 246-287, 1927.
________, Talc, Soapstone, and Pyrophyllite, AIME, Industrial Minerals and Rocks, pp. 873-892, 1938.

[3] B. C. Moneymaker, Talc Deposits of North Carolina (discussion), Econ. Geology, vol. 33, no. 4, 1938.

[4] J. M. Safford, Geology of Tennessee, 1869.
C. W. Hayes, Overthrust Faults of the Appalachians, Bull. Geol. Soc. Am., vol. 2, pp. 147-149.
G. W. Crickmay, Status of the Talladega Series in Southern Appalachian Stratigraphy, Bull. Geol. Soc. Am., vol. 47, pp. 1371-1392.

[5] Arthur Keith, The Great Smoky Overthrust, Bull. Geol. Soc. Am., vol. 38, pp. 154-155.

[6] G. W. and Anna J. Stose, The Chilhowee Group and Ocoee Series of the Southern Appalachians, Am. Jour. Sci., vol. 242, pp. 367-390 and 401-416, 1944.

In the present work, overlapping and subdivision of previously mapped units will be apparent. It should be kept well in mind that gradation, rather than abrupt change, is common among the rock types in the area described, and unit boundaries are not everywhere distinct in the field. The nature of the rocks of the area bears out older conceptions of comparatively rapid erosion and ebb-and-flow deposition of the original sediments, with intervening periods of quiescense. It follows that difficulty must be expected in correlating small lithologic units from one locality to another, and that the various facies should be considered only as lithologic tendencies of rocks that originally were laid down under constantly changing conditions of sedimentation, and which subsequently were affected by equally non-uniform conditions of metamorphism. Consequently, the term "formation" is used with reservation in discussions which follow.

PHYLLITE AND MICA SCHIST (PMS)[1]

Located northwest of the marble belt, as shown on the accompanying geologic map, is a series of rocks which formerly was included in Keith's Nantahala slate. Typically, the rocks are dark, banded phyllites ("slates") containing pyrite, staurolite, ottrelite, graphite, hornblende, biotite, and occasional garnets. The northwestern (upper) portion of the formation tends toward a fine-grained, sericitic schist which has repetitive zones of the other rock types. Usually confined to the more phyllitic portions are thin beds of dark, massive, micaceous quartzite, called "graywacke" by Keith. This quartzite commonly is medium-grained and arkosic and conglomeratic in places. On the southeast side (base) of the formation there is from 50 to 300 feet of massive quartzite-conglomerate. Also contained in the phyllites are gabbroid dikes or sills up to four feet thick and at least 20 feet along the dip. Their extent along the strike could not be observed. The rock is dark, coarse, predominantly hornblende and augite with smaller quantities of chlorite and vermiculite, and it appears to have been hydrothermally silicified. Many of the occurrences are adjacent to minor fold axes.

The character of the formation changes northeast from the town of Marble and southwest from the town of Murphy, reflecting original non-uniform lithology, and probably reflecting late alteration by hot solutions of deep-seated origin. Northeastward, to about the vicinity of Topton, the phyllites become more schistose and lose much of their accessory mineral content. From Topton to Wesser the formation gains quickly in both silica and carbonate, and gradation into the quartz-ottrelite gneiss, described below, is probable. Variations southwest of Murphy are less noticeable except for a darker color and an increase in silica content.

As in most of the other rocks of the area, internal structures are dominated by a major foliation dipping 45° to 90° southeast, along which considerable movement has taken place. Although small bedding faults and shear zones may be observed, it is likely that much of the stress to which the rocks have been subjected has been relieved along foliation planes. Several zones of minor folding have been noted but no major intraformational folds have been recognized.

QUARTZ-OTTRELITE GNEISS (QOG)

This formation crops out in the central part of the area under consideration. It is a part of Keith's Brasstown formation and appears as a dark, quartz-ottrelite-garnet gneiss containing biotite, hornblende, magnetite, and nodules and stringers of "pseudodiorite". Much of the quartz may be secondary, and a high sericite content in some parts of the rock may be the result of hydrothermal action. At several places the rocks are cut by quartz veins, up to six feet thick, which are accompanied by no accessory minerals other than thin scales of ilmenite and small patches of fine muscovite (Fig. 1). The quartz appears to lie in high-angle strike joints, though occasional blebs invade minor strike shear zones. The gneiss formation is more uniform across the strike than is the phyllite and mica schist described above, but changes along the strike are more pronounced. Schistosity increases markedly and the ottrelite content diminishes southwestward from Murphy. In the vicinity of the Nantahala River, the rocks appear to grade into the formation above, and the calcite content becomes high.

[1] Parenthetical script refers to symbols appearing on the accompanying geologic maps.

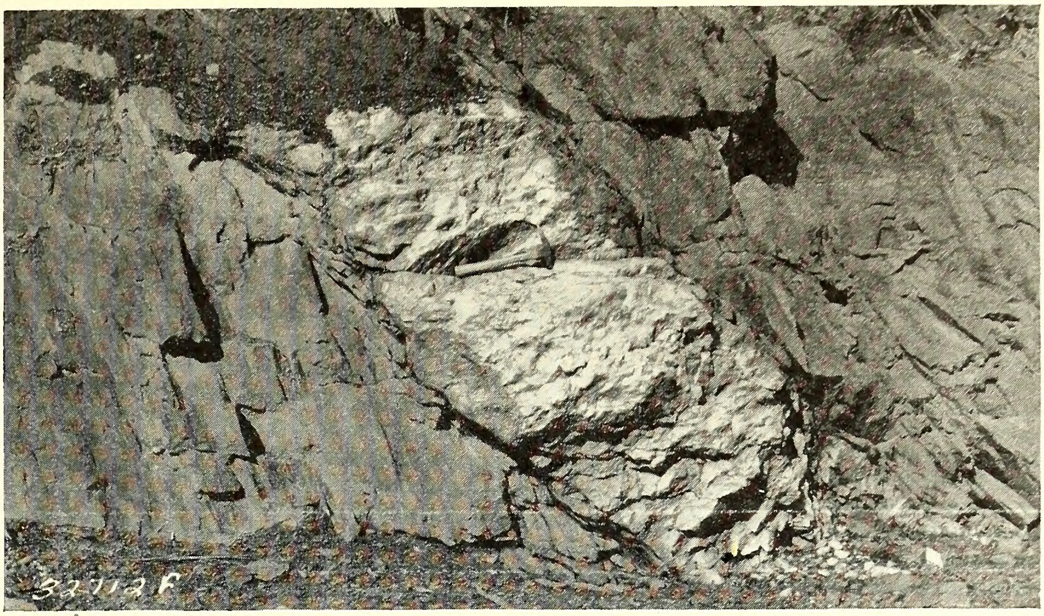

FIG. 1.—LARGE QUARTZ VEIN CUTTING QUARTZ-OTTRELITE GNEISS. RIGHT BANK OF THE HIWASSEE RIVER, OPPOSITE LOVER'S LEAP, NEAR MURPHY. LOOKING NORTHEAST.

Besides the major foliation already mentioned, flow cleavage and a lineation of cleavage intersections are prominent in the less massive beds. Large joint systems are rare and much of the imposed stress seems to have been absorbed along foliation planes.

QUARTZ-MICA GNEISS (QMG)

These rocks are more persistent as to type than any of those discussed above, probably because of their dense nature. Even the more schistose zones show quartzitic and conglomeratic relics. Although essentially gneiss, the formation contains massive quartzite which has been utilized, in more accessible locations, for rock quarries in state highway work. "Pseudodiorite", hornblende, and biotite are rather abundant in these quartzitic zones. Sericite is common in all of the formation, and ottrelite occurrences are not rare. The ottrelitic zones commonly contain garnet. Near the southeast contact of the gneiss, there is found an unusual type of arkosic quartzite that contains fragments of plagioclase. Most of the plagioclase seems detrital, but some of it has the appearance of secondary growth or rejuvenation as in the Hiwassee slate east of Irwin, Tennessee, and in the Little River slate near Lincolnton, Georgia[1]. Under the microscope it was noted that occasional metacrysts of secondary muscovite and chlorite are present. Whether by cause or by chance of observation, this secondary mineralization was especially noticeable in the vicinity of diorite outcrops and known talc occurrences.

Because of its dense, competent nature, the formation does not have well developed foliation planes as do the surrounding rocks, but an orientation of mineral grains is present. Small thrust planes and shear zones are common, as are systems of dip and oblique joints. Probably the most characteristic structure of the formation is a persistent zone of flat-lying, recumbent folds which suggest plastic deformation, some of the folds being unbroken and tightly closed for a distance of more than 20 feet along the dip.[2]

MICA SCHIST (MS)

Separating the quartz-mica gneiss from the Murphy marble is 200 feet or more of fine-grained, uniform mica schist which seems to represent a large shear zone. Probably related to the secondary mineralization just described are more or less random injections of pegmatite material, composed principally of

[1] C. E. Hunter, Personal Communication, 1947.

[2] Similar structures have been observed by the writer in many parts of the Great Smoky formation of North Carolina and in the Pigeon slate of Polk County, Tennessee.

plagioclase and quarts, but also including muscovite crystals up to one-half inch across. The material is distributed in migmatitic fashion through the rock.

Like the quartz-mica gneiss, with which it is included in Keith's Valleytown formation, the mica schist changes little along the strike. Thin quartzitic laminae become progressively numerous from Ranger to Culberson and the mica is somewhat coarser. In the interval between Hewitt and Wesser, the schist contains thin calcareous beds which give way to slate and quartzite to the northeast.

The formation is characterized by a prominent foliation, each plane of which has slickenside striae and a lineation of cleavage intersections, although lineation is difficult to recognize east of Hewitt. The presence of large diorite sills (See Page 14), just east of Hewitt and at Halls Ford at Kinsey (Near Talc Locality No. 5), indicates that contact with adjacent quartz-mica gneiss may be a major fault.

MURPHY MARBLE (MM)

As the Murphy marble is the only formation that contains talc deposits in the area, it is the formation with which this bulletin is most concerned and it will be described, therefore, in greater detail than are the other formations. Keith's terminology[1] is followed here because the formation is widely known and there is little chance of confusion with other rocks. The current work has resulted in a revision of structural interpretations, and has added to previous conceptions of the location, lithology, and mineralization of the marble.

General Distribution—In North Carolina the Murphy marble occurs in two geographically separated areas. The first and main belt extends from near Wesser to Culberson and on into Georgia, following along the Nantahala, Valley, and Nottely Rivers. The outcrop pattern is locally irregular as the result of domed and plunging folds and varying degrees of topographic re-entrant, and the marble is found both in stream bottoms and on the slopes. A second marble area is reported to extend from Peachtree, down Calhoun Branch and across Hiwassee River, thence following a narrow belt along Little Brasstown Creek to Martins Creek School[1], thence curving north down Martin Creek and west up West Fork of Martin Creek, thence down the headwaters of Caney Creek and possibly curving across to and down Gold Branch to Nottely River[2]. This stretch of marble, which will be described first, is a possible extension of the Cutcane Creek belt just to the southwest in Georgia[3], but evidence of a direct connection is lacking southwest of the Nottely River at Gold Branch.

Character of the Peachtree-Martin Creek Marble—Outcrops of these rocks are rare and previous mapping seems to have been based on indirect indications almost throughout. The few available exposures show light to dark gray banded marble, sometimes fairly pure but more often micaceous, and gray calcareous schist. Siliceous phases have not been observed. The rocks usually are fractured, with healing by calcite, and there is evidence of small and large folds which probably account for the sinuous trend of the formation. Adjacent rocks are pyritic ottrelite gneiss and ottrelite schist that contain limonite beds in the residuum, and finer grained mica schist, quartz-mica schist, and mica slates. Hypogene alteration is indicated in the rocks of the area by secondary quartz and sericite, and by epidote in associated siliceous boulders. On the property of A. Q. Ketner, near a cemetery just north of Martin Creek School, samples reported to be talc were taken from a field about 300 yards south of a marble exposure. The samples came from bed rock which is a relatively pure sericite schist well removed from a marble formation. The rock has many of the properties of talc and may contain a very small quantity of talc mineral, but sericite constitutes the mass. Bayley was told[4] that talc had been found at the mouth and near the headwaters of Gold Branch, but the writer could not find similar evidence either in the field or from persons living nearby.

Because of concealment afforded by recent stream deposits, upper terrace gravels (west of Macedonia Church), and generally deep overburden, it was decided early in the program that further work would be confined to the first and main marble belt which passes through Murphy, and work in the Peachtree-Martin Creek area was discontinued until the time when new road cuts, water wells, scoured stream beds, and

[1] Arthur Keith, 1907.
[2] W. S. Bayley, op. cit., 1925, p. 62.
[3] Laurence LaForge and W. C. Phalen, op. cit.
[4] W. S. Bayley, 1925, pp. 61-62.

other features will afford additional information. Future references to the Murphy marble belt in this report will exclude the Peachtree-Martin Creek area unless otherwise specified.

Extent and General Character of the Murphy Marble—Previous workers usually have referred to the Murphy marble as a formation consisting entirely of pure, rather fine-grained, recrystallized marble, more or less dolomitic, grading into mica schist on one side and ottrelite schist on the other, not uniform in color but predominantly white, and in places faulted out entirely (northeast of Andrews). "Its freedom from argillaceous and sandy materials, such as make up the entire bulk of the preceding formations, shows that the geographic conditions changed abruptly and entirely at that time."[1]

It has now been found that the Murphy marble is neither homogeneous nor unsymtematically heterogeneous, but that it is probably zoned in accord with accepted principles of sedimentation and petrology. It has been found also that facies which were originally sandy and shaly are important features of the formation and sometimes nearly displace the calcareous facies. A formation may be absent from its normal position in a sequence for one of three reasons: (a) the material was never deposited, (b) the material was deposited and later eroded, or (c) the material was deposited and later faulted out of position. Of course, the formation could be present and merely concealed from view. Faulting has been used in the past, with supporting evidence, to explain the apparent absence of the Murphy marble in certain localities, but equally good evidence now supports reason (a) in some places, and the problem of concealment cannot be ignored in others.

At the North Carolina-Georgia state line the marble is less than 200 feet thick. There are no good exposures, but indications are that much of the formation is represented by quartzite and mica schist, as it is a mile to the southwest in Georgia. Crossing the northern edge of Culberson, the marble follows a series of low depressions and is exposed in a quarry and railroad cut just west of where the Louisville and Nashville Railroad crosses Rapiers Mill Creek. It follows down the Nottely River past Ranger to a big bend in Nottely River at Stockade Mountain, and appears only as soft, white, calcareous material in stream beds and as calcareous schist at its transition into adjoining rocks. In the railroad cut in a low gap in a bend of Nottely River at Stockade Mountain there are several large, fresh outcrops of light-gray, tremolitic marble containing thin partings and scales of white talc and small blebs of vein quartz. Fragments of talc occur in the overburden but these seem to have been transported, at least in part, from higher up the slopes of the mountain. These outcrops are less than 50 feet from the marble-mica schist contact. About 1,000 feet west of Kinsey Station, in the same river bend, a small ledge of white and light-gray, fine-grained marble is in the bank of an abandoned quarry on the southwest side of the railroad.

The largest marble exposure in this section is in the Kinsey quarry (Map Location No. 5) though the marble can be seen only as irregular blocks on the south side. These include gray, blue, pink, and white varieties that are fine- to coarse-grained, both pure and with schist laminae up to three-fourths inch thick. Accessory muscovite, tremolite, actinolite, phlogopite, biotite, and pyrite are present. The most southeasterly exposures contain lentils or beds of talc up to 12 inches thick. A ledge of silicified marble measures four feet thick. The Kinsey talc mine is located at this quarry and will be described later.

At the Carolina talc mine, 3,000 feet to the northeast, white, fine-grained marble and dark, serpentinized (?) slates can be found on the mine dumps, but there are no surface exposures. Across Mulberry Gap, in a second bend of Nottely River, about 40 feet of weathered sandstone crops out at the Mulberry Gap mines of Minerals and Metals Corporation. This rock probably represents marble that has been completely silicified.

From Mulberry Gap, the marble generally follows down the Notteley River in which are occasional white marble ledges rising above the sandy bottom. Transitional calcareous beds are found in ledges of ottrelite schist along the old Louisville and Nashville Railroad bed. A small ledge of decomposed impure marble appears in the bed of Caney Creek, but from the valley of the Nottely River the marble can be traced northeastward only by talc exposures and topographic expression until it reappears in the bed of the Hiwassee River. In this interval it trends through Nancy Jordan Gap and the Hitchcock Corporation's Nancy Jordan and Cold Springs talc mines. At Section Six (Prospect No. 13 on Geologic Map) only transported talc appears on the surface, but a few small ledges of silicified marble can be seen in the bed of nearby Brit-

[1] Arthur Keith, 1907, p. 5.

tain Branch. Here also are dumps from old marble pits where lime was burned many years ago. Gold- and galena-bearing quartz veins have been reported at this location[1], and recent diamond drilling disclosed small galena-filled joints in white, fine-grained marble. A churn-drilled water well at Prospect No. 14 confirmed the location of the formation by intercepting dark blue, graphitic marble underlain by gray, medium-grained marble. At Prospect No. 15, a ledge of silicified marble crops out in the railroad cut beside J. B. Moore's house, and it is reported that white marble was intercepted by a diamond drill about 1,000 feet further northeast.

Gray, banded marble is exposed along a small stream, immediately west of Regal Station, by pits which were made in search of dimension marble. The famous Regal marble quarry, 400 feet southeast of Regal Station, is now filled with water, but it has been described in bulletins of the North Carolina Geological Survey[2]. This is the source of the Regal blue marble of which the Murphy courthouse is constructed. Blue and gray marble is reported to have contained graphite, amphibole, pyrite, quartz, and talc in small grains. Waste blocks, piled around the quarry, show many of these accessory minerals and also the cleavage, joints, and drag folds described by Loughlin, Berry, and Cushman[3] (See Fig. 5). The Regal quarry is situated near the stratigraphic base of the overturned formation (See Discussion of Folds, Page 40), and southeast of where the talc-bearing zone normally would be exposed.

Between Regal and Marble the formation can be traced by means of talc prospects and the positions of adjacent formations. One exposure of light-colored, tremolite-bearing marble is found on the Hayes prop-

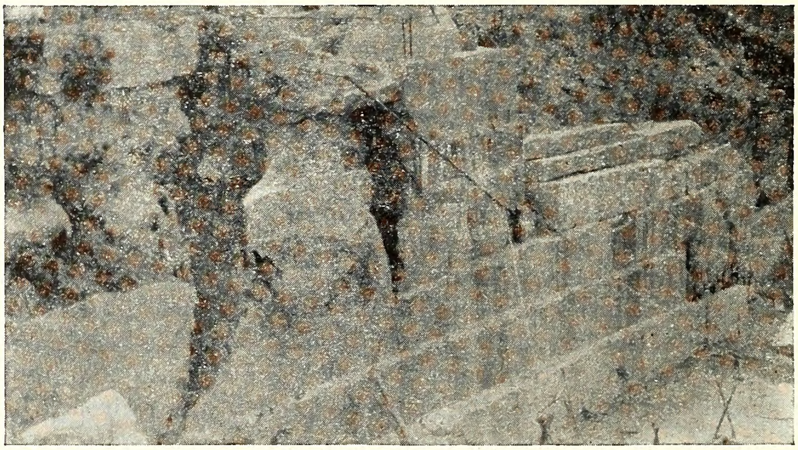

FIG. 2—OVERBURDEN AND SOLUTION CAVITIES IN QUARRY OF THE COLUMBIA MARBLE COMPANY, MARBLE, N. C. (PHOTO BY E. L. MILLER, JR.)

erty at a gauging station on Valley River at Tomotla. Near the mouth of Sam Branch, in a northeast-plunging anticlinal structure, a churn drill struck white marble at a depth of 26 feet. A southwest-plunging anticline is revealed in a marble quarry on Bettis Branch in the village of Marble. This dimension grade marble is light gray, of medium to coarse grain, and has small amounts of tremolite and pyrite. The gradational contact between marble and mica schist is quite clear in the crushed stone quarry farther to the north where siliceous and micaceous marble contains much muscovite and biotite and a few small grains of feldspar.

A small ledge of mottled white, fine-grained, dolomitic marble occurs in Hyatt Creek, 100 feet north of the highway. Beyond this point, the width of the area underlain by the marble increases greatly owing to a series of northeast-plunging folds, and the formation probably increases in true thickness as well. It is in this area that quarries of the Columbia Marble Company were located in the desirable blue marble. All but a recently opened quarry have been abandoned because of heavy water flow and excessive jointing, but information can be obtained from a study of the waste material. Only a rather coarse-grained rock is suitable for quarrying so that representative samples of the entire formation are lacking. The predomi-

[1] J. L. Stuckey, 1937, p. 1067.
[2] T. L. Watson and F. B. Laney, The Building and Ornamental Stones of North Carolina, N. C. Geol. Surv. Bull. no. 2, 1906.
G. F. Loughlin, E. W. Berry and J. A. Cushman, op. cit.
[3] Idem., pp. 38-40.

nating colors are blue and gray, and the stone, which contains individual calcite crystals up to three-eighths of an inch across, probably has a low magnesia content. Tremolite, and large cubes and small grains of pyrite are the usual accessories, occurring without regular orientation. Occasional blocks of finer-grained marble contain secondary mica and phlogopite and occasional splotches of secondary calcite. These rocks are mostly white, but in places are mottled with a pink color which may result from manganese impurities.

In the summer of 1946, the writer examined the last of the old Columbia quarries, immediately north of the machine shop, just before it was abandoned. Overburden from five to ten feet thick barely covered rock pinnacles which had an average relief of about five feet (Fig. 2). Enlargement of joints by solution seldom exceeded six inches and the largest cavities were approximately ten feet long by two feet wide. Most of the fractures were of an irregular incipient nature. The marble was of medium blue-gray and light-gray color, coarse-grained, with a faint banding which indicated the crest of an anticline plunging four degrees northeast. The newest quarry, now being opened, is barely inside the northwest edge of the Murphy marble on Welch Mill Creek, where bedrock occurs under ten feet of stream gravel and boulders. Medium-grained marble of white to light gray color contains random pink zones one to four feet thick. The attitudes of different beds reflect a series of northeast-plunging folds. Natural ledges of similar rock may be seen just across the creek to the east.

At the home of C. H. Townson, on a knoll south of the highway and a little west of north from the mouth of Welch Mill Creek, a dug well is reported to have bottomed in white marble at 50 feet, but a drilled well 40 feet away passed through white, tremolitic marble at 78 feet, and remained in feldspathhic ottrelite schist to a depth of at least 140 feet. At the first house east of Coalville Crossing, a drilled well showed white marble from 11 feet to at least 60 feet below the surface.

Both southwest-plunging folds and northeast-plunging folds are present in the area between Coalville and the western edge of Andrews; to the east from Andrews nearly all folds plunge to the northeast. Gray banded marble is exposed on a dirt road northeast from Valleytown Cemetery across Junaluska and Worm Creeks, and a few slabs of fine-grained white marble can be seen in Junaluska Creek southwest of Valleytown. Nearly all mapping of the marble between Coalville and Rhodo has been based on outcrops and structures of adjoining rocks.

Gray, medium-grained marble is exposed in a small abandoned quarry on the south side of Totherrow Branch at Rhodo. On the highway just west of the mouth of Jenkins Creek, thin marble beds have been seen in a strongly sheared, quartz-injected, black slate. From the mouth of Jenkins Creek to Nelson Creek fine-grained, white and gray, badly fractured marble occurs in ledges and in talc prospect pits. Much of this marble shows encroachment of originally sandy and shaly facies, until at Red Marble Gap the entire Murphy marble formation is represented by a white, leached, quartzite and mica schist totalling 25 feet thick. Equivalent thinning is reflected in the Nottely quartzite and the intervening mica schist.

From Red Marble Gap to a point opposite Rowlin School, the formation is obscured, but apparently it gradually thickens as the carbonate facies is resumed. Continuing on to Handpole Branch, marble is exposed regularly in several different belts as the result of repetition by northeast plunging folds, with calcareous, siliceous, and micaceous facies present. Notable are a large exposure of pink marble in a draw north of the railroad 1,300 feet west-southwest of the junction of U. S. Highway 19 and the Nantahala Powerhouse road and a white, siliceous, talc-bearing marble containing bluish quartz grains on the highway 300 feet west of the Swain-Macon county line (Talc Prospect No. 31).

Between Handpole Branch and Blowing Spring the marble formation attains a thickness up to 350 feet as it trends well up on the slopes above Nantahala River, exhibiting an irregular outcrop pattern from topographic re-entrants and constantly changing dips and strikes. Siliceous and micaceous facies occur erratically, and differences in the degree of alteration are reflected in zones of high muscovite, chlorite, amphibole, or talc content, as mentioned in later descriptions of talc prospects.

As is forecast by the apparent termination of the Nottely quartzite, the marble thins sharply to the east of Blowing Spring and disappears entirely beyond the peak shown as Bushnell No. 8. Wide expanses of adjacent rocks are quite calcareous farther on but it is not likely that they represent the Murphy marble as a formation. Rather they seem to reflect either the beginning or ending of the region's carbonate source.

Zoning in the Murphy Marble—Natural outcrops of the Murphy marble are so widely separated that the preparation of detailed geologic sections across the entire formation has been comparatively futile in the past. However, a careful study of the results of recent core drilling programs, coupled with the combined results of old and new geologic field work, has shed new light on the stratigraphy of the marble. Detailed core logs are now available from 12 holes in the vicinity of Hewitt, 6 holes at Marble, 5 holes at Section Six, east of Murphy, 20 holes at Hitchcock Corporation's Nancy Jordan talc mine, west of Murphy, 16 holes at the mine of Minerals and Metals Corporation on Nottely River, and 16 holes on the P. A. Mauney property west of Kinsey. The average depths of holes range from around 75 feet at the Minerals and Metals mine to well over 200 feet at Hitchcock Corporation's property. The most useful of the drilling programs, as a source of stratigraphic information, was on the P. A. Mauney property where 250 feet of an estimated total of 350 feet of marble section was cored.

Diamond drilling at the Hitchcock Corporation property (Location No. 10) gave the first indication of a stratigraphic sequence within the marble. When the first several holes were found to be amenable to correlation, the new-found data were applied successfully in outlining part of a large talc body, and unexpected additional reserves were forecast and later proven. The average section, converted to true thickness (perpendicular to the bedding), from top to bottom of the local attitude, was as follows:

40 Feet of blue-black to bluish-gray, coarse-grained, graphitic marble, occasionally stylolitic, with short (2mm) tremolite needles and rarely grains or clusters of pyrite. (Blue zone).

20 Feet of medium to light gray, medium-grained marble, sometimes stylolitic at top, with tremolite needles up to 10 mm long. (Gray zone).

15 Feet of light bluish-gray, fine-grained, lustreless marble, with or without tremolite, which is given a distinctive mottled appearance because of a myriad of small internal fractures. (Mottled zone).

45 Feet of white, medium to fine-grained dolomitic marble. This is the zone which is often partly silicified and which contains commercial talc deposits. (Talc or white zone).

25 (plus) Feet of mixed, sometimes banded, gray and white, medium to coarse-grained marble which contains thin beds of pink marble and accessory pyrite, phlogopite, actinolite, quartz, tremolite, muscovite, chlorite, and scapolite. (Mixed zone).

While drilling was in progress on Hitchcock Corporation property, a diamond drill program was begun by the Mauney Mining Company on property of P. A. Mauney (Location No. 4) and 12 holes were drilled at random in the northwest half of the marble belt. After an analysis of the Hitchcock drilling was explained, the Mauney Company drilled four additional holes in the desired location and disclosed a section which was practically identical to that on Hitchcock property.

Beginning at the bottom of the section just listed, the first stage of the Mauney Company's drilling showed marble zones as follows:

25 Feet of light and dark gray, banded, argillaceous marble, often jointed and brecciated, with accessory biotite, chlorite, and muscovite, and small specks of talc. (Slaty zone).

85 Feet of medium- to fine-grained marble, having intermittent zones of white, pink, and gray color, nearly all of which is characterized by the presence of actinolite clusters and pyrite, and which has considerable phlogopite in the lower portions. Sand grains, secondary quartz, and small scales of talc occur at random. (Actinolite zone).

20 Feet of dark micaceous marble and thin slate and schist laminae, having pyrite, chlorite, biotite, and muscovite. (Transition zone).

That portion of the marble section above the blue zone has not been cored, and correlation has been based on exposures principally in the bed of Hiwassee River at Murphy and in the quarries at Marble. From the ottrelite schist to the blue marble zone it is estimated to be as follows:

25 Feet of fine- to medium-grained white and light-gray marble, containing ottrelite and phlogopite, and having interbedded calcareous schist in the upper portion. (Transition zone).

25 Feet of white, medium- to coarse-grained marble having tremolite and pyrite. (Coarse white zone).

30 Feet of gray, coarse- to medium-grained marble having tremolite and pyrite. (Coarse gray zone).

After the Murphy marble had been subdivided, drill hole locations were laid out on the J. W. Bailey property, 500 feet south of the Mulberry Gap Mine (Location No. 7), and at the Section Six property (Location No. 13), with the result that core records conclusively substantiated previous findings. Similar corroboration was experienced on the Hartsfield property (Location No. 25) near Marble, except that the sequence was reversed since the beds were in their normal position instead of being overturned (See Page 19), and only parts of the white, mottled, and gray zones were cored. Core drilling at Hewitts was less successful only because excessive core loss resulted in less complete records. The general character of the cores coincided satisfactorily with the western area as did natural exposures of marble where the formation exceeded 150 feet in thickness. Thinning of the formation naturally disrupted correlation procedures.

Accurate information concerning changes in the various zones by thickening is not available, but it has been found that with a constant formational thickness the zones thicken and thin at the expense of each other, and that where talc replaces much of the white marble zone, the mottled zone is usually thinner and contains more tremolite and talc partings.

It is important to note that the white, talc-bearing zone is in nearly the exact stratigraphic center of the marble. It is, therefore, in the geographic center of the marble belt unless wide variations in overburden or surface topography alter its relationship to contact lines. Utilization of these relationships in the search for talc is explained in the section on exploration procedure. Although other zones of the marble have more or less quartz in conjunction with slaty and actinolitic phases stratigraphically above the talc, the central white zone seems originally to have had sandy material as an impurity in otherwise pure dolomitic limestone. Principally quartz, but having small quantities of rutile and zircon, the sand exhibits the roundness and equant grains of typical beach or shelf deposits. Such conditions, though curious, are not irreconcilable in view of the dolomitic character of the marble and in view of similar conditions which exist in Miocene marls of the Coastal Plain region of North Carolina: Twenhofel points out that many dolomitic sediments may represent shallower water conditions than do some of the purer lime sediments[1]; Stuckey reports conditions wherein Miocene marls contain up to 30 percent silica, mostly in the form of rounded quartz grains[2]. The sand possibly is introduced by a rolling of the grains along the basin floor rather than by a washing in of bulk material. At any rate, it is believed that the original sandy nature of the central marble zone was partly responsible (together with the dolomitic character) for the development of fractures in the marble, since the sand grains would assist in reducing the effectiveness of flowage, and these fractures permitted the entry of later solutions which silicified part of the marble and later formed the talc deposits.

OTTRELITE SCHIST (os)

As a separation between the Murphy marble and the Nottely quartzite, this formation (mapped by Keith as the northwest limb of the synclinally folded Andrews schist[3]) is present throughout nearly the length of the Murphy marble belt in North Carolina, but any one description does not suffice in all localities. From Valleytown to Ranger, the formation comprises brown, coarse ottrelite schist with smaller but uniform amounts of pyrite. The ottrelite crystals range up to three-eighths inch in size and usually are at an angle to foliation and bedding. Pyrite occurs as aggregates of minute crystals both in the mass and aligned in the cleavage. Most characteristic of the ottrelite schist is the formation of brown limonite crusts and beds in the residuum as weathering takes place. Gradation of the schist into the Murphy marble is broad and relatively smooth so that nearly half of the formation is calcareous. Transition into the Nottely quartzite is more irregular but no less certain. Variations in total thickness range from 200 feet to about 450 feet.

Northeastward from Valleytown and southwestward from Ranger, the ottrelite content decreases, both in size and quantity of the crystals, until a simple, finer-grained mica schist results and brown iron beds no longer are present. Except for stratigraphic position, this phase is nearly identical to the mica schist (ms) which lies just northwest of the marble.

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[1] W. H. Twenhofel, Treatise on Sedimentation, 2nd Ed., p. 346, 1932.
[2] J. L. Stuckey, Personal Communication, 1947.
[3] Arthur Keith, 1907.

Internal structures in this formation are similar to the structures in schists and gneisses previously described. A notable addition is the crenulation of primary cleavage planes and the development of fracture cleavage along the axial planes of the crenulations, parallel to minor fold axes. Slickenside striae are not so apparent and lineations other than crenulation axes are less noticeable.

NOTTELY QUARTZITE (nq)

As with the Murphy marble, the terminology of Arthur Keith is followed in denoting this formation since it is both characteristic and well-known by workers in the area. A part of Keith's description is quoted because it is in accord with present findings:

> . . . The formation consists entirely of white quartzite. As a rule, the shapes of the original grains of sand forming the rock are not visible except under a microscope. By that means (i.e the microscope) the original nature of the grains and their growth during metamorphism can be discerned. In some of the weathered outcrops and fragments the original form of the grains is again brought out when the secondary quartz has been dissolved away. Besides the quartz, a very small proportion of feldspathic material is usually present. Much of this was replaced by secondary quartz and muscovite during alteration of the rock. These latter minerals are now rudely parallel to the planes along which the motion took place in the rock. The schistose character thus introduced is strongest along the layers which originally were argillaceous or feldspathic. In some places the mica flakes become coarse and the rock approaches a quartz schist in appearance. As a rule, however, the quartzite is very fine-grained and glossy and is always white. . . .[1]

Only one major correction of Keith's description is required. The Nottely quartzite does not consist entirely of quartzite, due both to the presence of quartz schist layers and to beds which are nearly identical to the adjacent ottrelite schist. Also, in a bluff overlooking Valley River, about 100 feet upstream from the Southern Railway bridge in the town of Murphy, a two foot bed of marble was found in the quartzite.

Keith did not recognize the presence of the Nottely quartzite throughout the extent shown on the accompanying geologic map, but showed it as being faulted out in most places northeast of Tomotla. He stated that a white quartizite lay in contact with the marble at several places near Topton and Hewitt, but noted it as faulted Tusquitee quartzite. While the Nottely quartzite, as here used, certainly is not seen everywhere along its strike, it crops out at intervals close enough to warrant mapping as a continuous formation, and its stratigraphic and geographic position deny previous interpretations. East of Andrews it appears on the surface both as a hard, dense quartzite and as a mass of fine, white powder. Its termination at Hewitt may be explained partly by depositional conditions and partly by uncertain observations in difficult terrain. The nature of the Nottely formation has an important bearing on the Murphy marble. Further considerations are discussed in the description of the marble and of the general geologic structure of the area.

OTTRELITE GNEISS (og)

These rocks are similar to the ottrelite schist (os) and were considered a part of the same formation (Andrews schist) by Keith. The formation is principally brown, pyritic, ottrelite gneiss, generally siliceous, with phases of ottrelite schist and feldspathic quartzite. Also contained in at least two localities are diorite sills up to 40 feet thick. These are near the eastern city limits of Murphy and at Caney Creek, three miles southwest of Murphy. "Pseudodiorite" is found in the gneiss in small quantities. Weathering of the ottrelite gneiss produces beds of limonite in the residuum, resulting in the best known brown iron ores of Cherokee County.[2] Ottrelite has been found altered to vermiculite, but not in commercial quantities. Between Tomotla and Andrews, where the Nottely quartzite is indistinct, wide gradations back and forth between the two formations are likely. In manner similar to the ottrelite schist, ottrelite decreases in quantity along the strike southwest of Ranger and northeast of Andrews, giving way to mica schist and quartz schist.

Bedding, major and minor flow cleavages, fracture cleavage, and crenulations may be distinguished in most places, and a lineation of cleavage intersections parallel to fold axes is noticeable. In some of the quartzite beds a kind of boudinage structure shows elongation along the dip of the beds, but exposures were insufficient to allow acceptable measurements.

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[1] Arthur Keith, 1907.
[2] W. S. Bayley, op. cit.

STAUROLITE-MICA SCHIST (STM)

This formation is a part of what Keith mapped as the southeast limb of the synclinally folded Valleytown formation. Variations in lithology along the strike probably are more complex than in any of the other formations of the area. From Murphy to near Andrews, it is an ordinary staurolite-mica schist with zones of simple mica schist, dark micaceous quartzite and arkosic quartzite. Elsewhere the formation is barely distinguishable from the quartz-mica schist (qms) as it changes to chloritic and sericitic schist southwest of Murphy and to quartz schist, mica schist, and mica slate northeast of Andrews. Commercial flagstone has been quarried and sold on a small scale near Valleytown. Ottrelite, biotite, chlorite, hornblende, and secondary muscovite and quartz are accessory minerals.

Broad folding and (probably severe) faulting are in evidence, particularly in the vicinity of Marble and Andrews where shearing obliterates other internal structures at times. Interpretations of attitude were made possible by crenulations, occasional evidences of cleavage intersections, and a few small, more resistant quartzite beds.

QUARTZ-MICA SCHIST (QMS)

This series has not been mapped in its entirety because of its wide extent and remoteness from the talc-bearing marble, although studies were made in the vicinity of the Peachtree and Martins Creek marble localities. It is a series of quartz-mica schist and intermittent zones that probably represent original quartzites which resisted shearing action. Eastward from Topton, the rocks gradually become more dense and less schistose, with beds of massive quartzite becoming more prominent. Colors are light brown to dark gray. Much of the rock exhibits a characteristic "brassy" sheen on exposed dip surfaces, prompting the name Brasstown for the settlement after which Keith named his equivalent formation.

In his Brasstown formation Arthur Keith recognized lithologic variations which could not be attributed entirely to folding, and it is easy to interpret his description as that of a series rather than a formation. However, much of the rocks previously mapped as Tusquitee quartzite are now believed to be stratigraphically separated facies or remnants within the quartz-mica schist. The entire series appears to be a zone of thrust faulting at, or near, an anticlinal axis, though it has not been possible to determine the prevailing attitude of bedding because of strong foliation which more or less parallels the generally steep, southeastward-dipping beds.

DIORITE (DO)

Igneous rocks in the Murphy marble belt and surrounding areas have received little notice from geologists in the past. LaForge and Phalen[1] and Emmons and Laney[2] briefly mentioned gabbro dikes from the Ducktown copper area, and field workers have noted smaller but similar exposures near Bryson City, Swain County, North Carolina. Local workers have also recognized a large diorite dike or sill, similar to those described herein, in the vicinity of the Fontana and Adams Copper Mines in Graham County, North Carolina. A somewhat different type of igneous-appearing rock, "pseudodiorite," has received attention in geologic literature and is described later.

Current work has revealed for the first time[3] the nature and extent of a series of diorite sills which occur about 300 feet to 450 feet stratigraphically above and below the Murphy marble. Exposures have been found northwest of the marble near Hewitt and at Kinsey, and southeast of the marble at the eastern city limits of Murphy and on Caney Creek three miles southwest of Murphy. The rock has the same general appearance in all localities, being of dark gray-green color, granitic to porphyritic texture, and showing varying degrees of alteration. The term diorite is used advisedly, but there is so little feldspar showing that the rocks might be termed pyroxenite and amphibolite. The lack of feldspar and quartz, however, may be due to alteration by later solutions, and the term "metadiorite" might be preferable. Marked schistosity

[1] Laurence LaForge and W. C. Phalen, U. S. Geol. Survey, Geol. Atlas, Ellijay Folio, no. 187, 1913.
[2] W. H. Emmons and F. B. Laney, U. S. Geol. Survey, Prof. Paper 139, Geology and Ore Deposits of the Ducktown Mining District, 1926.
[3] The TVA Geologic Division has on file a thin section (No. 42) of "uralite schist" collected from near Kinsey, but the present writer was not able to re-establish the field locality.

is seldom present, although secondary chlorite, biotite and quartz cause a platy appearance in some places, and altered mica schist in the contact zones may be mistaken for sheared diorite.

Just east of Hewitt a diorite sill, about 40 feet thick, has been traced for about two miles along the mica schist and quartz-mica gneiss contact (Fig. 3). Strike and dip appear to conform with the country rock throughout. The rock has a fine groundmass of chlorite and biotite with more or less quartz, muscovite, and feldspar. Phenocrysts are light-green actinolite and darker uralite. Under the microscope, zircon and tourmaline were found and the feldspar was identified as andesine. Contact metamorphism is not evident by megascopic examination but petrographic studies of adjacent rocks reveal chlorite, zircon, zoisite, hornblende, and pyroxene.

At Halls Ford, near Kinsey, six miles southwest of Murphy, a sill measuring 38 feet in thickness has been traced across a big bend of the Nottely River for about one mile, following the contact of the mica schist and the quartz-mica gneiss. Outcrops range in size from a few feet to blocks 15 feet high and 20 feet wide. It is difficult to distinguish the rock from quartzite except by close inspection, although occasional outcrops exhibit peculiarly irregular surfaces upon weathering (Fig. 4). Certain small zones have a high carbonate content, and they weather like limestone or marble. Unoriented phenocrysts of actinolite are up

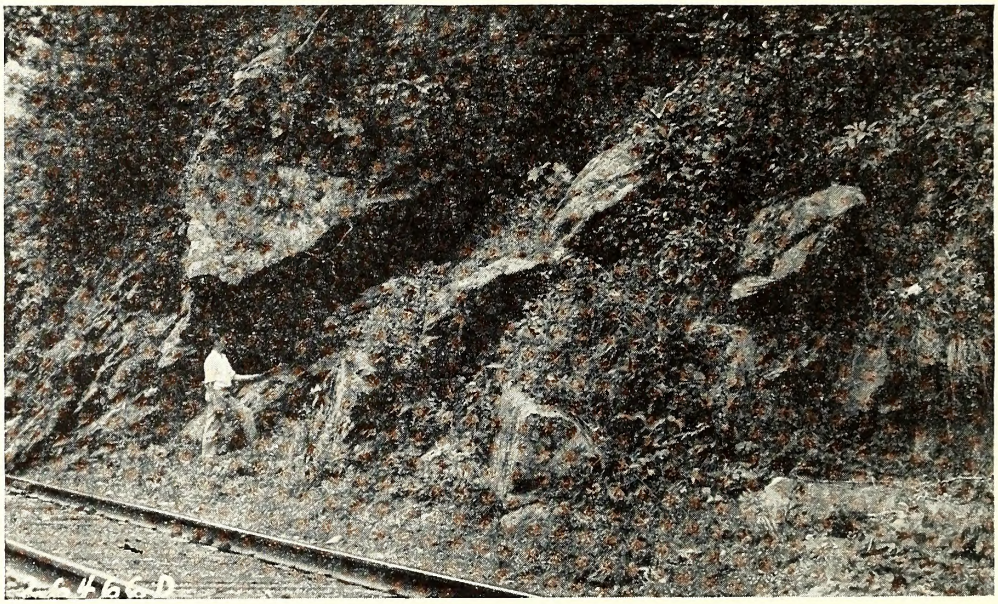

FIG. 3—DIORITE (BETWEEN THE FIGURE AND THE CAMERA), ON THE SOUTHERN RAILROAD, POLE NO. 2331, 1.7 MILES EAST OF HEWITT. LOOKING SOUTH.

to three-eighths inch long, being larger than in the sill near Hewitt. Petrographic study of two specimens did not reveal any feldspar or quartz in the fine ground mass of chlorite and muscovite. Schistosity is poorly developed and bedding is not visible so the dip and strike could not be measured on the ground. Adjacent rocks are too deeply weathered to allow determinations of contact metamorphism or transition into the country rock.

Southeast of the Murphy marble, near the contact between ottrelite gneiss and staurolite-mica schist, evidences of sills are less certain. At the Murphy Cannery, just north of U. S. Highway 19 at the eastern city limits, a dark-green dioritic or gabbroic rock may be seen within ottrelite gneiss. Hornblende and actinolite crystals occur in a quartz-chlorite-feldspar groundmass with a few pale pink garnets, and small inclusions of ottrelite gneiss occur within the sill which seems to have a thickness of about 30 feet. The rock is dense and hard since the small amount of chlorite and excess of quartz is not conducive to the platy nature of similar exposures elsewhere in the area. Scarcity of outcrops necessitated mapping mostly on the basis of float and altered schist, and the accompanying geologic map shows an extent of less than 2,000 feet.

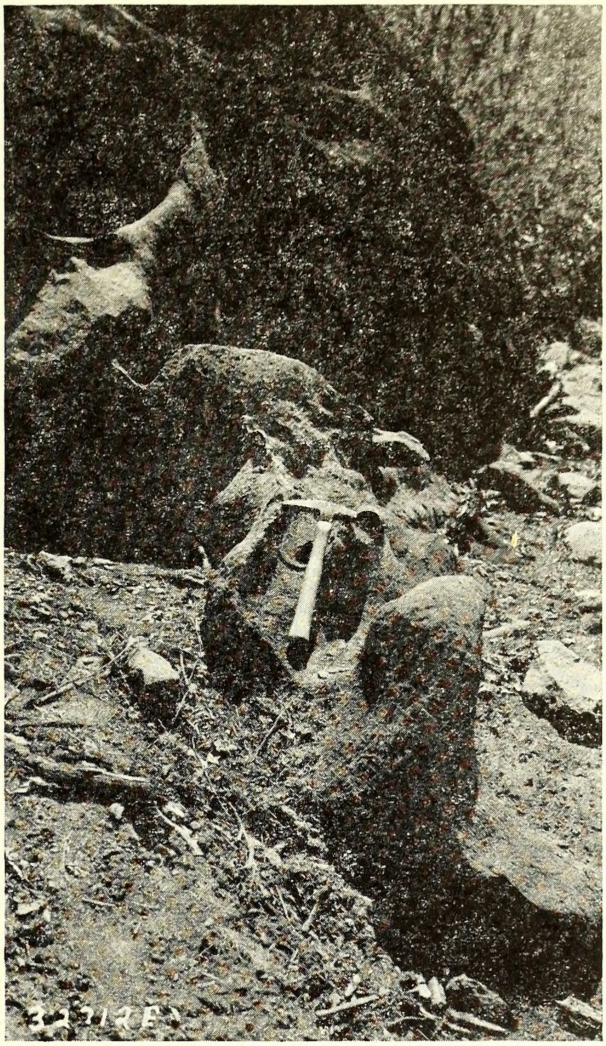

FIG. 4.—DIORITE ON RIGHT BANK OF NOTTELY RIVER AT HALLS FORD, NEAR MAP LOCATION NO. 5. LOOKING SOUTHWEST.

Diorite outcrops and float have been mapped for about 4,000 feet near the mouth of Caney Creek southwest of Murphy. Best exposures are in the creek bed and bank and in a borrow pit on the south side of U. S. Highway 64. The petrography is similar to that of the Kinsey sill, showing no feldspar, little quartz, and a few small specks of manganese oxide.

Some indications of the structure of the sills already have been given. Little or no schistosity is apparent, attitude seems to conform with the country rock, and systematic joints are absent. Because of difficulty in recognizing the existence of these rocks, it is not improbable that other exposures will be found in the future along the two contact lines. It is certain, however, that the sills are discontinuous along the strike and probably along the dip as well. The fact that the sills have been found in the same stratigraphic position over a distance of nearly 35 miles is indicative of possible fault plane control.

In addition to these large, well-defined igneous sills, mention has been made of gabbroid dikes or sills which are present in the phyllites to the northwest. They range from a few inches to at least four feet in thickness and have been measured up to 20 feet along the dip, but they have not been recognized along the strike. They are similar to gabbro dikes in the Ducktown region and nearly identical to gabbros in Keith's Nantahala slates on the Tuckaseegee River below Bryson City. Large augite and uralite crystals are set at random in a groundmass of very fine quartz with smaller amounts of chlorite and brown biotite. Colors range from dark brown to greenish-black. Schistosity is almost entirely absent and the rock is so tough as to firmly resist breaking with a pick. Ordinarily the intrusives are parallel to steeply dipping beds, but they have been found pushed up in the centers of small anticlines. Because of their small size, no attempt has been made to show these rocks on the accompanying geologic map.

Direct evidences of rare or commercial minerals have not been found associated with these various types of igneous rocks, though indications of them may show up in representative chemical analyses. It seems probable that these rocks are inter-related with late alterations of the rocks of the area (formation of late quartz, muscovite, chlorite, biotite, amphiboles, pyrite, phlogopite, etc.), with the formation of "pseudodiorite," and finally with the formation of talc deposits. These factors will be considered later in discussions of the talc.

"PSEUDODIORITE"

Not to be confused with the above mentioned diorites and gabbros are small nodules and stringers of a light-colored, igneous-appearing rock which Keith originally called quartz diorite dikes[1] and later called pseudodiorite[2]. Other writers have added to Keith's descriptions[3]. Briefly, the rock is a white quartz-feldspar groundmass with both oriented and unoriented metacrysts of hornblende and garnet, together with occasional biotite and calcite. Varied degrees of zoning usually exist as hornblende metacrysts become smaller and more numerous toward the outer edges of the bodies. Most of the formations other than the Murphy marble and the dense white quartzites contain some "pseudodiorite."

OVERBURDEN AND WEATHERING

In the area of the Murphy marble belt, dock weathering and the transportation of weathered debris are dependent on geologic structure nearly as much as on rock composition. Coarse, schistose rocks are usually more resistant to chemical decomposition than many other types, possibly because percolating ground waters move faster in the schists and do not have time to attain heavy concentrations of corrosive agents. In consequence, coarse schists are commonly found to have a minimum average thickness of overburden. Very dense, hard quartzite is the most resistant of all rocks in the area, but slight increases of structural weakness and of easily weathered minerals result in fairly deep overburden. Gneisses and fine-grained schists are most susceptible to weathering, and they usually have the deepest residual mantle. Pure marble, when fractured, is attacked by ground waters and dissolved with comparative rapidity, but all material is carried away and no residuum remains in place. As the percentage of impurities in marble increases, weathering characteristics become more nearly like those in other types of rocks and some form of residuum may be formed.

Specifically, experience has shown that in localities where talc exploration and mining are carried on along the Murphy marble, the thickness and type of overburden varies more or less with elevation. In low valley bottoms, the marble is covered by from 5 to 20 feet of silt, sand, gravel, and small and large boulders. Overburden ranges from 20 feet to 80 feet on the higher benches and sides of valleys, and contains fewer boulders and thicker sands and clays. On higher benches and in the gaps, total overburden may be as much as 130 feet, usually averaging 60 feet to 80 feet. Top gravels and boulders are rare except along the Nantahala Gorge, and float of the Nottely quartzite is not abundant enough to cause difficulty in core drilling work.

GEOLOGIC STRUCTURE

ORIGINAL DEPOSITION AND GENERAL STRUCTURE

The general character of original sedimentation in the southern Appalachians has long involved ideas of rapid erosion and rapid deposition in irregular, discontinuous basins. For example, if one pictures the conditions under which deposits are being formed today along our southeastern coastline, with its sinuous

[1] Arthur Keith, 1907.
[2] Arthur Keith, Production of Apparent Diorite by Metamorphism, Geol. Soc. Am. Bull., vol. 24, pp. 684-685, 1913.
[3] Laurence LaForge and W. C. Phalen, op. cit.
W. H. Emmons and F. B. Laney, op. cit.
C. S. Ross, Origin of the Copper Deposits of the Ducktown Type in the Southern Apalachian Region, U. S. Geol. Surv., Prof. Paper 179, 1935.
B. C. Moneymaker, Character of the Great Smoky Formation in the Hiwassee River Basin of Tennessee and North Carolina, Tenn. Acad. Sci., vol. 13, no. 4, pp. 291-93, 1938.

inlets, sounds, bars, peninsulas, and islands, and if one further pictures cyclic ingress and egress of the sea, the complex possibilities of gradation and hiatus are apparent. Imagine these calcareous deposits, sands, and silts being solidified, pushed up, crumpled, sheared, and partly eroded; such processes are involved in the geologic history of our present inland rock formations. In the vicinity of the Murphy marble belt, conglomerates, quartzites, gneisses, schists, and marble show intergradation, and their relations to each other are affected by folding and fracturing and by the injection of hot, aqueous liquids and vapors derived from underlying igneous masses. With these conditions in mind local changes along and across the strike of formations can be explained.

FOLDS

In his mapping of the Nantahala quadrangle[1], Keith concluded that the Murphy marble and adjacent formations were part of a broad syncline in which the marble was prevented by faulting from reappearing southeast of the fold axis. It seems likely that much of Keith's theory was based on the outcrop patterns of folds in the Murphy marble and on the idea that all folds plunged to the southwest, thus requiring a synclinal structure as the only logical interpretation if his data were sufficient.

Between Culberson and Andrews, a study of cleavages northwest of the Murphy marble shows with little doubt that southeast-dipping beds are overturned, except in the minor folds, in all rocks from the phyllite and mica schist (pms) to the mica schist (ms). Similar studies at Murphy indicate overturning in the ottrelite schist (os) and ottrelite gneiss (og). Although few internal structures of the Murphy marble point conclusively to overturning, features that might characterize overturned beds have been recorded inadvertently as far back as the work[2] of Loughlin, Berry, and Cushman (See Fig. 5).

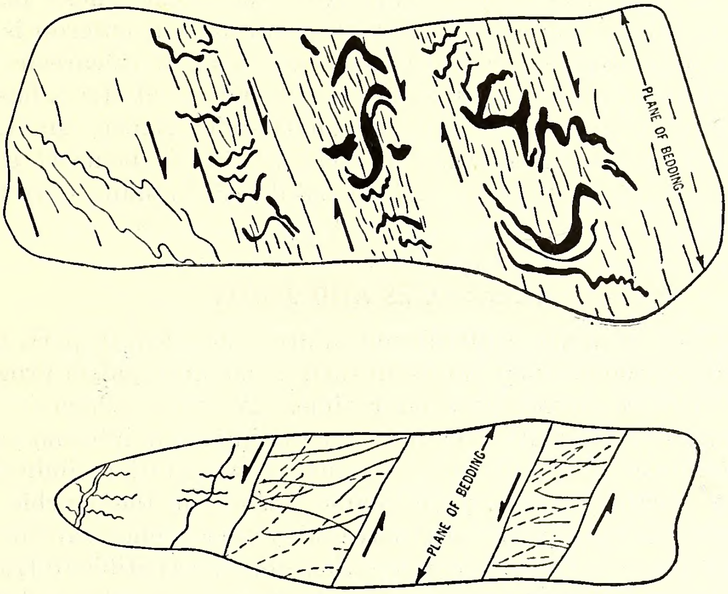

FIG. 5.—SKETCHES SHOWING INTERNAL FRACTURES IN MARBLE FROM REGAL QUARRY (AFTER LOUGHLIN, BERRY AND CUSHMAN). ARROWS HAVE BEEN ADDED TO SHOW RELATIVE MOVEMENT AND POSSIBLE INDICATIONS OF OVERTURNING. ANTICLINES WOULD BE IN DIRECTION OF HANGING-WALL SIDES.

The presence of overturned southeast-dipping beds over such a broad area can be explained satisfactorily by assuming them to be part of the northwest limb of an overturned anticline. Further evidence of anticlinal structure is seen by comparing the outcrop pattern of northeast-plunging folds with the pattern of southwest-plunging folds in the Murphy marble (See Geologic Map). A blanketing schistosity renders cleavage analysis undependable in most of the rocks southeast of the marble belt, but a few indications of normal stratigraphic sequence have been found in the quartz-mica schist (qms). This might lead

[1] Arthur Keith, 1907.
[2] G. F. Loughlin, E. W. Berry, and J. A. Cushman, op. cit., pp. 38-39.

to the assumption, which requires confirmation by additional study, that the Peachtree-Martins Creek marble is a part of the southeast limb of the anticline.

Dip and strike vary from place to place along the Murphy marble belt, but for estimating and projecting purposes it is convenient to use N45°E for the strike and 50°SE for the dip. Bedding is often parallel to schistosity but deviation may occur in a critical locality. The most accurate criteria for bedding determinations are banding and facies changes, and all other criteria should be regarded with suspicion, but even banding might be caused by non-conforming structures. The most satisfactory method is to compare several criteria and check one against another.

FAULTS

References to minor faults have already been made in the preceding discussion. Fault planes that show considerable movement have not been observed directly, but drag structures indicate that such faults do exist near some of the minor folds in schistose and gneissic rocks. In connection with rocks of the Great Smoky and Hiwassee formations, where structures are of the same age and general type as are those along the Murphy marble belt, the writer has reported that normal fault zones having dip slips of up to 200 feet measured in tenths of feet in width, whereas thrust faults having little slip exhibited shear zones of ten feet or more[1]. Similar conditions should be expected in rocks adjacent to the marble.

As was disclosed in the section on folds, stratigraphic interpretations do not require postulation of the Murphy fault[2], nor are the faults of the Stoses[3] necessary to an explanation of the position of the Murphy marble-Andrews schist-Nottely quartzite group of rocks. If these faults are non-existent, the Murphy marble is a part of the Ocoee series and is older than either the Great Smoky formation or the Nantahala slate. The failure of the marble to reappear northwest of its present outcrop is not incongruous, because it is probable that original conditions of sedimentation did not allow calcareous sediments to extend very far along the dip. As has been noted, however, a very great amount of stress has been relieved throughout the mica schist (ms), staurolite-mica schist (stm), and quartz-mica schist (qms), and hundreds of feet of displacement could be represented in any of these formations. It is believed that the actual amount of displacement cannot be determined until many additional detailed studies have been made along the trend of these formations.

CLEAVAGES AND JOINTS

The fractures produced by dynamic metamorphism are controlled, in part, by the relative competency of the rocks involved. Relative competency varies in turn as metamorphism progresses, so that older fractures influence fractures which are formed at a later time. A stress which is applied slowly in coarse, crystalline marble can be relieved, without fracture, by a gliding along internal planes of individual crystals and a subsequent recrystallization of the marble. A number of conditions indicate that such an action has taken place in a part of the Murphy marble: pure, coarse phases of the marble are relatively free from fractures even though differential movement must have taken place; fine-grained dolomite and impure marble, however, was less capable of rescrystallization and, therefore, susceptible to fracturing which gave access to mineralizing agents. These conditions have a direct bearing on the size and position of talc deposits.

Flow cleavage and fracture cleavage are foliate structures which are of prime importance in the Murphy marble belt. Flow cleavage is present in beds of incompetent micaceous rocks, and nearly parallels the limbs of folds. Fracture cleavage is an equivalent structure of the denser, more competent quartzites and marble and is more nearly perpendicular to the limbs of folds. Both cleavages may be used, with a few exceptions, to determine whether the rocks in which they occur are overturned or in a normal position. The acute angle of intersection of cleavage and bedding will point in a direction which, if followed along the bedding, leads to the crest of an anticline (Fig. 6). Cleavages provide paths for mineralizing agents and are common locations of secondary minerals.

All rocks in the area of the Murphy marble belt exhibit a more or less common regional foliation termed schistosity. Secondary fractures were formed during the later stages of metamorphism, and these new

[1] Unpublished TVA report, Geology of the Apalachia (dam and tunnel) Project, May 1943.
[2] Arthur Keith, 1907.
[3] G. W. and Anna J. Stose, 1944.

fractures attempted to follow the cleavages which had been formed previously. Thus, the schistosity is a special combination of flow cleavage and fracture cleavage. The schistosity usually has a steep southeast dip, roughly parallel to bedding except where minor folds cause bedding planes to vary while the schistosity continues unchanged. Movement along the planes of schistosity is reflected in striae or grooves from a fraction of an inch up to two or three inches across. Schistosity is less severe in dense quartzites and nearly absent in the marble, but incipient weaknesses are revealed where secondary mica and other platy or acicular minerals have been formed.

A great deal of the stress imposed on rocks of the area has been relieved by foliation in the schists and gneisses, and extensive joint systems are prominent only in more competent quartzites and in fine-grained, dolomitic phases of the marble. Joints do not extend for long distances, nor do joint systems seem to have very distinctive orientation, although it is likely that trends might be revealed if many hundreds of joints

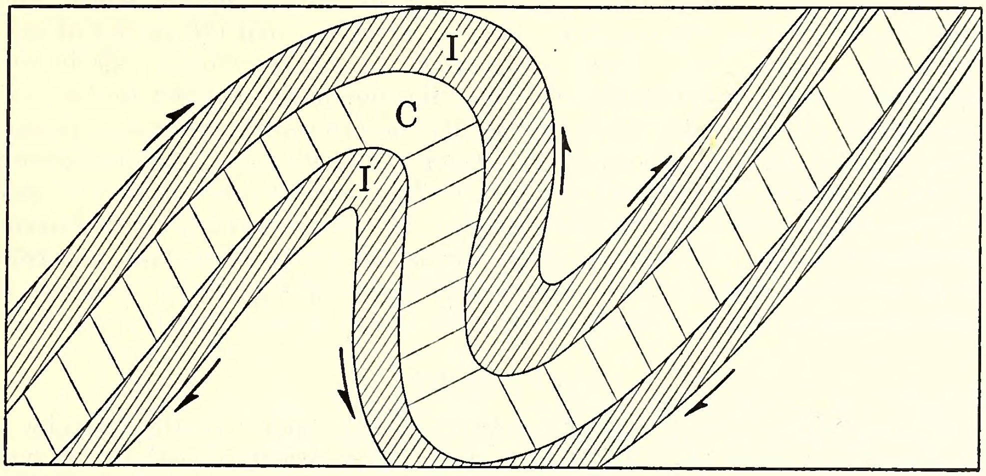

FIG. 6.—SCHEMATIC CROSS-SECTION SHOWING RELATION OF CLEAVAGES TO FOLDS IN COMPETENT (C) AND INCOMPETENT (I) ROCKS. ARROWS INDICATE DIRECTION OF RELATIVE MOVEMENT ALONG BEDDING.

were plotted on polar nets. Subsequent movement is apparent in many joints of the area and innumerable comparative age groups of joints are represented. Because of the manner in which planes of foliation and bedding are interconnected by joints, percolating ground water has greater penetration and more readily weathers the country rock.

LINEATION

The term "lineation" can be applied to various types of linear phenomena in rocks, such as fold axes, striae, flow lines, elongations and intersections. The cleavages described above appear as lineations when they are seen in section only as a single line or group of parallel lines. Lineations may be denoted by their pitch, which is measured by protraction from the horizontal within the plane on which the lines are seen, or, more simply, by their plunge, which is measured from the horizontal by means of a clinometer, in the vertical plane that includes the bearing of the plunging line. Carefully weighted results of lineation studies are helpful in deciphering geologic structures, since lineation is controlled by movements which have taken place, with particular reference to axial planes of folds.

Slickenside striations form one class of lineation that occurs widely in this area. The striae usually plunge southwest on planes of schistosity but sometimes have other directions of plunge on joints, bedding planes, and small faults. Easily confused with thesestriae are lineations formed by the intersection of cleavages, where the trace of one cleavage plane shows on another as a tiny ridge or crack. The direction of plunge of cleavage intersections on schistosity planes has been demonstrated to correspond to the plunge of minor folds along the Murphy marble belt, allowing structural interpretations which have been obscured heretofore. In the present work, it has been found that talc bodies of the area also plunge in accord with cleavage intersections, as do many other types of ore bodies in the southern Appalachian region.

In the ottrelite gneiss, southeast of the Notteley quartzite, a form of lineation known as boudinage has been observed in several exposures, particularly in a road cut opposite the Murphy cannery. Stretching parallel to fold axes appears to have pulled siliceous rocks apart by tension, resulting in separated blocks which are elongated parallel to fold axes. One other form of lineation is represented in conglomerate beds of the Great Smoky formation at Mill Dam, three miles northwest of Murphy, where maximum elongation of stretched pebbles is approximately parallel to fold axes.

GEOLOGY OF THE TALC DEPOSITS

STRATIGRAPHIC CONTROL

In the section on zoning of the Murphy marble, it was pointed out that the approximate stratigraphic center of the formation is occupied by a fine-grained, white, dolomitic marble which sometimes contains talc deposits. Many dozens of observations show without exception that talc bodies of any commercial size are not found outside this central zone. Other portions of the marble contain talc in the form of scales, partings, and small pockets, and certain slaty zones near the northwest contact of the marble are talcose, but these cannot be termed talc deposits. Reports that talc occurs near the marble contacts have been based on the position of talc which later was proved to have been moved by slumping and creeping. Other erroneous data have resulted from concentration of originally disseminated talc scales or of minor quantities of tremolite which has been altered to talc. Caution must be exercised when attempting to correlate the occurrence of talc in localities where the Murphy marble formation is extremely thin and composed mostly of quartz and micaceous material. These conditions are analyzed in the section dealing with the marble formation.

STRUCTURE

Configuration of the Bodies—The lenticular tendency of talc bodies in the Murphy marble has been recognized at least since the report of J. H. Pratt in 1900[1], and recent investigations have convinced the writer that all talc bodies of commercial size are roughly lens-shaped. Indications are that these lenticular bodies have echelon arrangement, with a "line of bearing" parallel to the strike of the marble in which individual lenses vary from the local strike in amounts depending upon the degree of plunge (Fig. 12). Lenses that have been discovered thus far plunge either northeast or southwest at an average angle of about 18° from horizontal, varying from zero to as much as 35°. Dimensional ratios of the talc bodies could be used to good advantage in explorational work, but extreme variations render valueless any theoretical fixed ratios other than to say that strike length is greater than thickness or breadth. Actual "pinching out" of the talc in any direction may occur by fingering, transition, or breaking up into smaller isolated bodies, although experience has shown that the presence of marble inclusions in the main body can be mistaken for "pinch-out" warnings.

Controlling Structures—In the sections Zoning in the Murphy Marble and Cleavages and Joints, it was pointed out that the central talc-bearing zone of the marble is dolomitic and especially liable to fracturing. Since the attitudes of talc bodies are known to coincide with foliate structures, and since it is doubtful that the structures are of post-talc age, it might be assumed that both the attitudes and shapes of the talc bodies result from similar attitudes and shapes of fracture systems.

In order to explain the lenticular nature of the talc bodies, it must be realized that rock deformation seldom results from uni-directional forces, but rather from multi-directional forces which twist and either compress or pull apart. Fracture systems, like folds and lineations, attain plunging attitudes by the influence of later unbalanced (e.g. tilting) forces, and as fracture systems must have spatial limits, it is natural that they exhibit gradations in severity. Thus, a fracture system can be so deformed that it attains an ellipsoidal outline within which the individual openings are large near the center of the system and nonexistent beyond the outer edges. If other suitable mineralizing conditions exist simultaneously or subsequently, mineral deposits may be formed in, or controlled by, these three-dimensional zones of weakness.

In summary, the talc deposits have their present shapes and attitudes because the action of complex forces resulted in simple, ellipsoidal systems of weakness which controlled the travel of talc-forming agents.

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[1] J. H. Pratt, op. cit.

Internal Structures—The various talc deposits have internal structures which differ from place to place only in degree and direction. Common to nearly all of the talc, and parallel to regional schistosity, is a minutely spaced cleavage which gives the talc a fibrous or foliated nature. The origin of this cleavage is obscure, although several possible explanations can be advanced. One possibility is that the talc might have replaced schistose marble in such a manner that the original foliation pattern was reproduced much as grain is reproduced in petrified wood. Objections to this theory are that foliation is stronger in the talc than in adjacent marble, and, in addition, slickenside striae are present in the talc but are seldom found in nearby marble. The explanation favored by the writer assumes that talc formation took place during a lull in rock deformation near the end of the last great period of metamorphism (Carboniferous age) and that only slight movement occurred after the talc was in place. The theory allows for those few examples of massive talc which are known to exist (principally at Hewitt) and conforms to observed data which have been derived from studies of certain other mineral deposits and igneous intrusions. It certainly does not seem probable that the talc could be in its present condition if it had been subjected to the full force of movements which caused regional schistosity.

Although joints are present in talc bodies, they are, for the most part, younger than any of the other structures, and seldom pass into the surrounding marble. Intervals between joints are rather wide, at least several feet. Excepting movement that has taken place along the foliation, few important faults are found in the talc. One irregular normal fault of unknown displacement occurs in the Nancy Jordan Mine. It strikes nearly 45° from the principal foliation and dips vertically. In talc bodies which have distinct footwalls and hangingwalls, movement seems to have occurred along the walls approximately parallel to the local direction of plunge. Lineations of cleavage intersections may be seen on planes of the principal foliation and occasionally on footwalls and hangingwalls. These lineations are always parallel to the local trend of the talc body's long axis.

One type of internal structure that has not been explained satisfactorily is a kind of roll around the longitudinal axis of the talc lens. Rolls occur on both footwall and hangingwall and are the means by which the talc thins and thickens along the dip. At the Mulberry Gap Mine, the hangingwall has a fairly constant dip but the footwall undulates. At the Nancy Jordan Mine both walls have rolls, and similar conditions exist at the Carolina Mine. In most of the currently accessible talc pits and adits at Hewitt, rolls are confined mostly to the hangingwall.

MINERALOGY OF THE TALC DEPOSITS

The average grade of commercial talc in the Murphy marble is of high quality as compared to talc from other parts of the country. One set of weighted averages, derived from data of the U. S. Bureau of Mines[1], indicates total impurities amounting to less than four per cent. Impurities noted in those samples were ferrous iron, carbonates of calcium and magnesium, rutile, zircon, and epidote. Other minerals which have been observed from time to time include tourmaline, garnet, monazite (a single grain), muscovite, chlorite, phlogopite, pyrite, magnetite, amphibole, zoisite, scapolite, and serpentine (?). Of these minerals, talc, quartz, amphibole and carbonate are associated the most intimately.

The following descriptions of minerals are based on megascopic observations supplemented by petrographic studies. Unfortunately, sampling for petrographic work was erratic. Most specimens were collected early in the program in search of criteria which might be used to predict the location of talc bodies along the strike. Nearly all talc-quartz specimens are from a common horizon (bottom) of the talc. Complete chemical analyses of talc from the different deposits have not been made recently, but several older analyses are available.

Talc—The color of the fresh talc varies from pure white (equal to standard magnesium carbonate) through greenish-white, green, blue, and gray. Variation in color may be due in part to the refraction of light through minute fracture systems. All of the talc is fibrous to some extent, although at Hewitt some varieties have most of the properties of massive talc. Fibrous structure does not prevent the talc from having good strength when cut into crayons, and large talc blocks can withstand severe treatment without

[1] U. S. Bureau of Mines: Survey of the Suitability of Domestic Talcs for High-Frequency Insulators, R. I. 3804, April 1945.

breaking down. In the vicinity of hangingwalls and footwalls, it is not unusual to find very hard glazed talc with the grain curved on short radii. In this connection it should be explained that footwalls and hangingwalls do not delimit the occurrence of talc. A mixture of talc and marble or talc and quartz continues for a few inches or even feet beyond the walls.

The petrography of the talc appears to be rather complex. Some thin-sections of pure talc show a marked orientation of elongate talc, while others show little uniformity as reflected in extinction positions. Talc has been observed to replace tremolite, quartz, carbonates, muscovite, phlogopite, and various heavy minerals, and it has been found to follow cleavage planes between individual minerals without alteration of either talc or accessories. Large unaltered crystals of tourmaline and tremolite have been found imbedded in talc, and there are indications that talc may have been replaced at times by muscovite, clinozoisite, and apatite. Where talc occurs as disseminated scales and partings outside the main talc zone, little evidence of replacement can be seen, and it is possible that the talc is merely an interstitial filling or, at most, a replacement of equally thin fillings of secondary quartz or mica.

In the large talc bodies the transition from talc to marble and/or quartz is gradational. Smaller isolated talc pockets and fingers have rims of mixed talc and wall rock, and "footwalls" and "hangingwalls" do not cause sharp contacts. On the other hand, changes in the quality of talc within a single body tend to be abrupt, and contacts between grades have plunges comparable to those of the parent masses of talc.

Quartz—Three distinct types of quartz are contained in both the marble and the talc deposits. Vein quartz is the most rare and possibly the least important. Stuckey[1] reports the occurrence of probable vein quartz in dumps of the Hayes prospect (Location No. 20) at Tomotla, where large masses of cherty quartz show replacement by small quantities of tremolite and talc.[2] At Section Six (Location No. 13), the writer has found chunks of glassy quartz, twelve inches by four inches, which showed definite replacement by talc. Smaller quartz veins (up to one inch thick) have been seen in talc, marble, and silicified marble at the Mulberry Gap Mine. Definitely rounded detrital sand grains have been found in talc bodies and in silicified marble all along the Murphy marble belt from Hewitt well into Georgia. These grains are fairly rare in masses of pure talc in areas where the carbonate facies are reasonably thick, but they are more abundant where quartzitic and slaty facies begin to encroach. However, sand grains are quite noticeable near the outer edges of talc bodies where masses of silicified marble are adjacent to the talc.

From time to time, references have been made to silicified marble almost as if it were a separate zone or rock type. Such an allusion is convenient and is probably not incorrect. The term refers to a rock, a part or all of which is quartz, that apparently once was marble. At the Mulberry Gap Mine, this siliceous rock attains a thickness of nearly 40 feet, and it is equally thick on the southwest side of Talc Mountain at Hewitt. In other places it is less thick and some talc bodies contain the rock in the form of nodules or "kidneys" from a few inches to several feet across. Studies of thin sections of the silicified marble indicate that some quartz individuals are definitely rounded and apparently detrital, while others are sub-rounded as if they had been partly resorbed. It is possible that some, but not necessarily all, of these rounded quartz grains are similar to those in the Gaffney (South Carolina) marble, where Kessler found a similar shape in quartz grains that blended into patchy aggregates. These aggregates in turn blended into definitely nonclastic quartz veinlets whose marginal grains had the same rounded outlines.[3] However, most of the quartz individuals in the silicified zone of the Murphy marble have irregular outlines and are grouped in homogeneous masses suggesting hydrothermal origin. Lineation in the mass of the silicified marble is more apparent in hand specimens than in thin sections. Much of the quartz is replaced by talc directly and in other places the talc occurs along microscopic shears. The quartz is also replaced by tremolite, tourmaline, carbonates, phlogopite, muscovite, chlorite, zoisite, zircon, and pyrite, and it in turn replaced carbonate, muscovite, zircon, and possibly tremolite.

Carbonate—Calcite and dolomite are important chiefly because they go to make up the marble which contains talc. Calcite is of further importance as an impurity, being undesirable in ceramic talc. Beyond the possibilities mentioned in the section on general geology, the original source of the marble is obscure

[1] J. L. Stuckey. Personal Communication. 1946.
[2] J. L. Stuckey, 1937.
[3] T. L. Kessler, Personal Communication, 1947.

and will not be discussed again. It is possible that secondary calcite has been introduced hydrothermally but a re-use of already available calcite can satisfy all the requirements needed in explaining phenomena of calcite occurrences. Dolomite is needed because it is possible that the talc deposits would not have been formed had not some (but not necessarily all) magnesia been already present. It has been observed that calcite is replaced by talc, quartz, tremolite, tourmaline, phlogopite, chlorite, muscovite, zoisite (or clino-zoisite?), zircon, and pyrite. Individual carbonate grains in the marble vary in size from sub-microscopic to nearly one-half inch, and comparisons with chemical analyses indicate the possibility that the finer-grained marble is more likely to have a high magnesia content. Two types of carbonate occurrences are present within talc bodies. The first is in the form of unaltered inclusions of marble (kidneys) which may be found distributed non-uniformly. The second type is in the form of vugs and veinlets of crystalline calcite which are encountered in only a few places, particularly near the edges of talc bodies.

Amphibole—Stuckey[1] reports the occurrence of hornblende in the Murphy talc and all workers have mentioned, with varying emphasis, the presence of tremolite and its iron-bearing relative, actinolite. Hornblende in either the marble or talc has not been observed by the writer. Actinolite is widely distributed throughout the marble formation and usually is accompanied by pyrite. Commercial talc bodies rarely contain actinolite although the white (talc-bearing) marble zone may contain actinolite where talc is not present.

Pratt[2] believed that most, if not all, of the Murphy talc resulted from an alteration of tremolite. While tremolite certainly alters to talc, the writer is doubtful that any talc deposits of commercial size are derived directly from tremolite. In the Murphy marble, tremolite is found in sizes from microscopic particles to bladed crystals up to 20 inches long. It occurs as individuals and as oriented and unoriented aggregates in all parts of the marble formation. Tremolite replaces and is replaced by talc and most of the other accessory minerals, demonstrating several different stages of formation, but tremolite probably was never present in the quantities previously supposed.

Although tremolite is intimately associated with talc, experience has shown that it is never abundant in and about the larger talc deposits, but often it is abundant within the central white marble zone when talc is not an important constituent of the rock. When tremolite replaces quartz or marble, it gives the illusion of sharp needles bodily piercing the invaded material[3]; but when tremolite crystals are replaced by talc, it is not unusual for the talc to form as a broad encroaching wave. Tremolite is not a satisfactory criterion in the search for talc because it is present in so many parts of the marble. However, the writer has noted a marked increase of tremolite as drilling progressed along the strike away from known talc deposits.

Other Minerals—Pyrite is distributed throughout every horizon of the Murphy marble, especially in the slaty, actinolitic, and mixed zones. It ranges in character from minute specks to cubes up to one inch across, and occurs as disseminated particles and as coatings on joint faces. Pyrite is least abundant in the talc and in white, fine-grained dolomite, although it is an important impurity in some of the talc in Georgia near the state line. Tourmaline occurs sometimes as the black, iron variety, schorl, and more often as the brown, magnesium variety, dravite. Dravite crystals, up to three inches long, have been found in silica zones separating talc from marble in the Nancy Jordan Mine and in mixtures of talc and tremolite at Maltby. Crystals of black tourmaline have been found in otherwise pure talc at the Mulberry Gap Mine, but these crystals seldom exceed one-quarter inch in length. The presence of tourmaline, together with magnetite, lend credence to theories of high temperature mineralizing conditions. Sericite and chlorite have been observed in many of the impure phases of the Murphy marble. Chlorite is seldom seen in association with large talc bodies, but sericite is rather common, especially in the gray "sheened" talc.

Approximately 200 pounds of talc sawdust from one location was panned down, originally in search of magnetite. The panned concentrates of black sand amounted to about two tablespoonfulls, and examinations under the microscope disclosed well rounded grains of rutile, zircon, epidote, zoisite, garnet, ilmenite, magnetite, and a number of unidentified minerals, as well as quartz sand. Detrital heavy-mineral grains also have been found in thin sections, but, in addition, rutile, zoisite, zircon, and epidote of almost certain primary occurrence have been seen.

[1] J. L. Stuckey, 1937.
[2] J. H. Pratt, 1900.
[3] J. L. Stuckey, 1937.

In drill cores where the white marble zone was intercepted without finding commercial talc, irregular masses of scapolite, about one inch across, have been identified. These possibly may have resulted from the alteration of feldspar fragments, or they might have a primary origin. Phlogopite usually is present in the scapolite localities and is not an unusual member of the outer zone around talc bodies and in the mixed and slaty marble zones.

On the dumps of the Carolina Talc Company mine, near Kinsey, are fragments of a dark green, slate-like rock with greasy lustre and feel. The material is fairly soft and has many of the characteristics of serpentine, though identification under the microscope was not positive. The writer has not seen this material in place, but its occurrence on the talc "footwall" has been reported.[1]

CHEMICAL COMPOSITION OF THE TALC

Gillson notes that definite conclusions have not resulted from the numerous studies of the chemistry of talc. "The analyses show that the ratio Mg:Si varies from 1:1 to 4:3 and the water content from 3 to over 7 per cent. Most reference books on mineralogy gives the formula as $H_2Mg_3(SiO_3)_4$. According to this, the mineral should carry 63.5 per cent SiO_2, but published analyses show a range from 56.86 to 62.10. MgO should form 31.8 per cent in the 1:3:4 type, but actual analyses vary from 27.9 to 32.40. Alumina, ferric and ferrous iron, manganese, and lime are reported in various analyses, although the purity of the material analyzed may be open to question in some cases." Gillson intimates that pure talcs are rare and that some of the desirable properties of commercial talc result from impurities.[2]

The National Bureau of Standards made tests on a Manchurian talc which had the following properties:

MgO	=	32.32 per cent
SiO_2	=	61.34 per cent
CaO	=	Trace
R_2O_3	=	0.71 per cent (mostly Al_2O_3)
Ign.	=	5.81
Ratio $MgO:SiO_2:H_2O$	=	4:5:1.54

Heat treatment showed that water in excess of one molecule was driven off at 380°C-500°C. No change in crystal structure was noted up to 800°C. At 800°C-840°C the talc decomposed into enstatite, amorphous silica, and water vapor, abruptly changing the thermal response curve. Only slight changes in the curve were noted when enstatite converted to clinoenstatite at 1200°C and amorphous silica converted to cristobalite at 1300°C.[3]

Nearly every commercial grade of talc can be produced in quantity from the Murphy area, the grades depending on the presence or absence of clay, quartz, tremolite, carbonate, rutile and zircon, iron, and sundry coloring materials. Consequently, chemical analyses may vary over any desired range. Colors range from dark gray-green, through a pleasing yellow which was marketed as "Goldex," to a pure white which has been measured by the photometer as 100 percent of the whiteness of standard magnesium carbonate.

In its Report of Investigations 3804 (1945), the Bureau of Mines did not publish complete analyses of Murphy talc, but samples from drill cores and shallow pits showed from 1.36 to 2.20 per cent Fe_2O_3, 0.04 to 0.09 per cent CaO, and from a trace to 2.0 per cent rutile and zircon. The following table shows the complete analyses that are available, together with selected representative analyses from other areas.

[1] C. E. Hunter, Personal Communication, 1947.
[2] J. L. Gillson, 1937.
[3] Nat. Bur. Stds. Jour. Research, RP. 848, 1935.

TABLE I

CHEMICAL ANALYSES OF TALC

Sample		Location	SiO_2	MgO	Fe_2O_3 Al_2O_3	CaO	Ign	Other
0		Theoretical	63.49	31.75	------	------	4.76	------
1	a	Maltby, N. C.	61.60	31.24	2.10	0.24	4.88	------
2	c	Maltby, N. C.	56.80	23.98	10.90	.140	6.14	0.77
3	a	Regal, N. C.	52.68	29.70	9.62	0.16	7.29	------
4	a	Hewitt, N. C.	62.08	30.62	2.22	0.14	4.96	------
5	c	Hewitt, N. C.	61.35	26.03	6.10	0.82	5.10	0.55
6	a	Murphy, N. C.	58.54	31.04	3.60	0.22	5.15	------
7	c	Kinsey, N. C.	63.07	28.76	2.23	0.30	4.36	1.28
8	b	Murray Co., Georgia	40.75	20.50	22.36	3.69	11.37	0.46
9	b	Murray Co., Georgia	59.72	27.93	8.26	0.90	3.19	0.08
10	b	Murray Co., Georgia	46.24	26.00	14.44	4.76	8.37	0.09
11	d, e	Talladega, Alabama	61.67	30.71	1.54	0.32	4.66	------
12	f	Waterville, Vt.	61.06	28.60	6.52	Trace	3.92	------
13	f	Gouverneur, N. Y.	62.10	32.40	1.30	------	2.05	2.15
14	g, h	Inyo Co., California	59.68	31.36	2.29	0.37	5.57	0.73

a. TVA files.
b. A. S. Furcron and Kefton H. Teague, Talc Deposits of Murray County Georgia; Ga. Geol. Sur. Bull. 53, 1947.
c. J. H. Pratt, op. cit.
d. Lynn McMurray and Edgar Bowles, Talc Deposits of Talladega County, Alabama; Ala. Geol. Sur. Circ. 16, 1941.
e. Average of three samples.
f. R. B. Ladoo, Talc and Soapstone: U. S. Bur. Mines Bull. 213, 1923.
g. U. S. Bur. Mines, RI 3804, 1945.
h. Sierra Talc. Average of five standard samples.

ORIGIN OF THE TALC

PREVIOUS INTERPRETATIONS

For background information concerning the genesis of talc in other localities, the reader is referred to the excellent summaries and conclusions of Gillson, who made a thorough study of the literature on talc, supplemented by personal experience.[1] In his report on the Vermont talc he states: "Few students of talc deposits have given the attention to the mineralogy and paragenesis which seem to be necessary to an adequate conception of talc formation. From the evidence of the Vermont deposits, and the published descriptions which have been reviewed, the following general conclusions have been drawn:

1. Talc deposits are commonly lens-shaped, and of irregular occurrence and extent.
2. Talc deposits are replacement deposits in limestone, schists, gneisses, and altered basic intrusions.
3. The country rock of talc deposits is almost invariably old, at one time deeply buried probably at the time of the talc formation.
4. The types of solutions that form talc, whatever was the original rock replaced, first formed amphibole or a chlorite. * * * * * * * * These solutions were hot, alkaline, and were at first siliceous and carried iron and calcium and some aluminum in addition to magnesium. Later solutions became less siliceous and rich in magnesium.
5. In many cases, if not in all, these hot solutions were emanations from granitic or dioritic rocks or from the acid differentiates of basic intrusions.

The conditions of depth, high temperature and character of solutions had to be fulfilled in order that talc might form."[2]

Harker[3] believed that talc is formed by dynamic metamorphism and Keith[4] was of the same general opinion. H. Ries[5] attributed talc to the action of magmatic solutions. J. H. Pratt[6] thought the Murphy talc

[1] J. L. Gillson, 1937.
[2] J. L. Gillson, Origin of the Vermont Talc Deposits, Econ. Geol., vol. 22, 1927.
[3] A. Harker, Metamorphism, 1932.
[4] Arthur Keith, 1907.
[5] H. Ries, Economic Geology, 1930.
[6] J. H. Pratt, 1900

resulted from alteration of tremolite. Stuckey concluded that the Murphy talc and associated minerals were formed by hot magmatic solutions and listed his criteria as:

1. Occurrence in irregular lenses.
2. Gradational character of the contacts between talc and marble.
3. Silicification of the marble.
4. Presence of quartz veins within talc and marble.
5. Presence of marble "kidneys" within talc bodies.
6. Presence of non-oriented tremolite in talc and marble.
7. Microscopic evidence of replacement.

Stuckey lists the probable sequence of events as:

1. Formation of Cambrian sediments.
2. Metamorphism (Appalachian Revolution).
3. Formation of igneous masses.
4. Silicification of the marble.
5. Development of accessory minerals by replacement of marble and quartz.
6. Development of talc by replacement of tremolite and marble, and coincident development of pyrite and magnetite.[1]

NEW DIAGNOSTIC CRITERIA

A more or less definite zoning within the Murphy marble has been revealed. Listed in descending stratigraphic order from top to base, a typical section of the marble, with accumulative depths is as follows:

		Mica schist (ms)
MURPHY MARBLE	0 feet	Transition zone
	20 "	Actinolitic zone
	105 "	Slaty zone
	130 "	Mixed zone
	155 "	White (talc-bearing) zone
	200 "	Mottled zone
	215 "	Gray zone
	235 "	Blue zone
	275 "	Coarse gray zone
	305 "	Coarse white zone
	330 "	Transition zone
	355 "	Ottrelite schist (os)

The white talc-bearing zone is a dense, fine-grained dolomitic marble which is slightly sandy in places. Some of the zones are rather pure calcium carbonate, while others are micaceous and have a high alumina content.

Evidence of deep-seated magma is found near the talc in the form of diorite sills which lie 300 to 450 feet stratigraphically above and below the Murphy marble, of pegmatite material which occurs in a migmatitic manner in nearly mica schist, and of gold-galena-bearing quartz veins which are found within the marble.

In order to prevent excessive repetition, reference is made to data presented in the section on mineralogy of the talc. In summary, the paragenesis in descending order from the youngest to the oldest minerals seems to be as follows:

[1] J. L. Stuckey, 1937.

Carbonate		
Quartz		
Apatite		
Zoisite	Muscovite	Quartz
Scapolite	Tourmaline	Amphibole
Phlogopite	Pyrite	Talc
Amphibole	Magnetite	Muscovite
Chlorite	Rutile-Zircon	Phlogopite
		Amphibole
		Chlorite
		Quartz
		Carbonate

Some of the late quartz and carbonate have cold solution relationships.

The talc occurs in ellipsoidal bodies which lie parallel to, and plunge with, local fold axes, and which are coincident with definite systems of lineation.

Although surrounding rocks are severely folded and fractured, excessive movement does not show in the internal structures of the talc. Studies of general geology in the area indicate that the talc was formed under many thousands of feet of sediments.

GENESIS OF THE MURPHY TALC

On the basis of foregoing criteria, the following deductions are made: It is obvious that the Murphy talc did not result from cold water alteration of original material. Neither does it seem that sufficient magnesia and silica were present in the original marble to allow the formation of talc by simple dynamic metamorphism. It is believed that the central, slightly sandy, dolomitic zone allowed the formation of zones of weakness by dynamic metamorphism. Later hot aqueous solutions of granitic and/or dioritic origin ascended along and into zones of structural weakness and at least partly silicified the dolomite. A coincident or later wave of hot solutions ascended and formed lenticular talc bodies because an optimum amount of silica, magnesia, and catalysts were already available. Minute quantities of talc were formed in adjacent marble, but either insufficient magnesia, silica, or catalysts were present, or too much alumina and other materials were available to allow the formation of more abundant talc. Similar mineralizing solutions are believed to have formed the abundant sericite, ottrelite, and other minerals, as well as "pseudodiorite," in several thousands of feet of adjacent quartzites, schists, and gneisses.

These conclusions are in accord with the work of Stuckey and of Gillson except that an intermediate chlorite or amphibole phase is not postulated.

ECONOMIC ASPECTS OF THE TALC

The characteristics of pure and impure talc are utilized in a great number of commercial products and processes. Block talc is sawed into crayons for use in marking metal, cloth, and similar materials. Powdered or granulated talc is used in cosmetic preparations, including soap and lotions; as a filler and lubricant in cloth; as a filler in paper, rubber, asbestos, and composition materials; as a lubricant and absorbent in dies and molds; as a pigment and extender in paint; as a constituent of dispersing agents and pharmaceutical supplies; as a polishing agent; and as a welding rod coating. More recent and very important uses for talc result from its ceramic properties. Certain block (lava) talcs are machined and fired to form parts which must stand excessive electric and thermal shock. Powdered talc is used in a talc-clay grog (steatite) extruded into molds and fired for purposes similar to the lava talc. Steatite is also used in the manufacture of sagger bodies, cordurite, and to a lesser extent in the manufacture of whiteware.

No crude talc is shipped from the Murphy area. Much of the talc is sawed into crayons, packed one gross to a carton, and shipped in crates of 24 cartons. All other talc is pulverized at from 90 per cent minus 100 mesh to 98 per cent minus 200 mesh and shipped in 50 pound paper bags. The pulverized talc is used principally in cosmetic, textile, and food polishing industries. Small shipments sometimes are made to supply high grade talc in blocks for art work. The Murphy area does not supply the lower grades of talc for use as roofing granules or for the other economy markets. However, it is probable that stained, impure surface talc could be supplied.

When the Hewitt mines were in production prior to 1925, ceramic grade talc was utilized for the manufacture of gas tips but no other attempts have been made to enter the ceramic markets. Recent studies by the U. S. Bureau of Mines indicate that talc from the Murphy marble can be beneficiated to a degree suitable for steatite talc, [1] and it is hoped that producers and research agencies will continue this work. It should be emphasized that larger quantities of new grades of talc have become available since the last samples were tested, and it is possible that unbeneficiated talc of suitable steatite quality is now available. By adopting methods formerly used at the Hewitt mines, the Hitchcock Corporation had firing tests made on talc which was mined and allowed to cure in the cool darkness of the Nancy Jordan Mine for about two weeks. The resulting fired shrinkage and checking was notably less than that of freshly mined talc.

Mining and milling costs in recent operations are not available, but it is believed that normal estimating methods can be applied with a fair degree of accuracy. Accurate prices of processed talc can be obtained only through reputable buyers, but it is probable that the average price of talc products from the Murphy area exceeds $50 per ton, f.o.b. Murphy area, including both crayons and pulverized talc. Prices of pulverized talc are quite variable but talc crayons are fairly well stabilized at the equivalent of from $350 to $400 per ton in in individual cartons.

Talc reserves in the Murphy marble belt are more than adequate for long term operations. Indicated reserves on three properties alone amount to a quarter of a million tons crude, and probable reserves are proportionally high. There is still plenty of room for additional exploration work with good chance of success as compared with other types of mineral exploration, and much of the "guess work" has now been removed.

The writer has been told by reputable talc producers and buyers that the Murphy talc can and does compete favorably with standard and premium talc of California, France, and Italy. One of the principal barriers to rapid expansion has been the past history of sporadic, undependable talc production in North Carolina, but the industry is now firmly entrenched and is building a good reputation among buyers. One other restraining factor has been the exotic sales appeal of imported foreign talcs whose qualities easily may be equaled in this country. The needs today are increased exploration by core drilling, exploitation of deposits already known, utilization of low grade material, continuance of scientific mining and milling methods, close laboratory control, and more diligent sales promotion. These, together with the freight cost advantage over more distant deposits, can easily raise North Carolina to higher rank as a producer of superior grades of talc.

DESCRIPTIONS OF DEPOSITS

The locations described are shown by corresponding numbers on the accompanying geologic map. These are locations of talc outcrops, prospects, old and new mines, and sites of exploration of one kind or another. Descriptions of the older work has been obtained from published material and from information supplied by persons who were associated with the work. Sources of information not received from published literature will not be acknowledged in every instance.

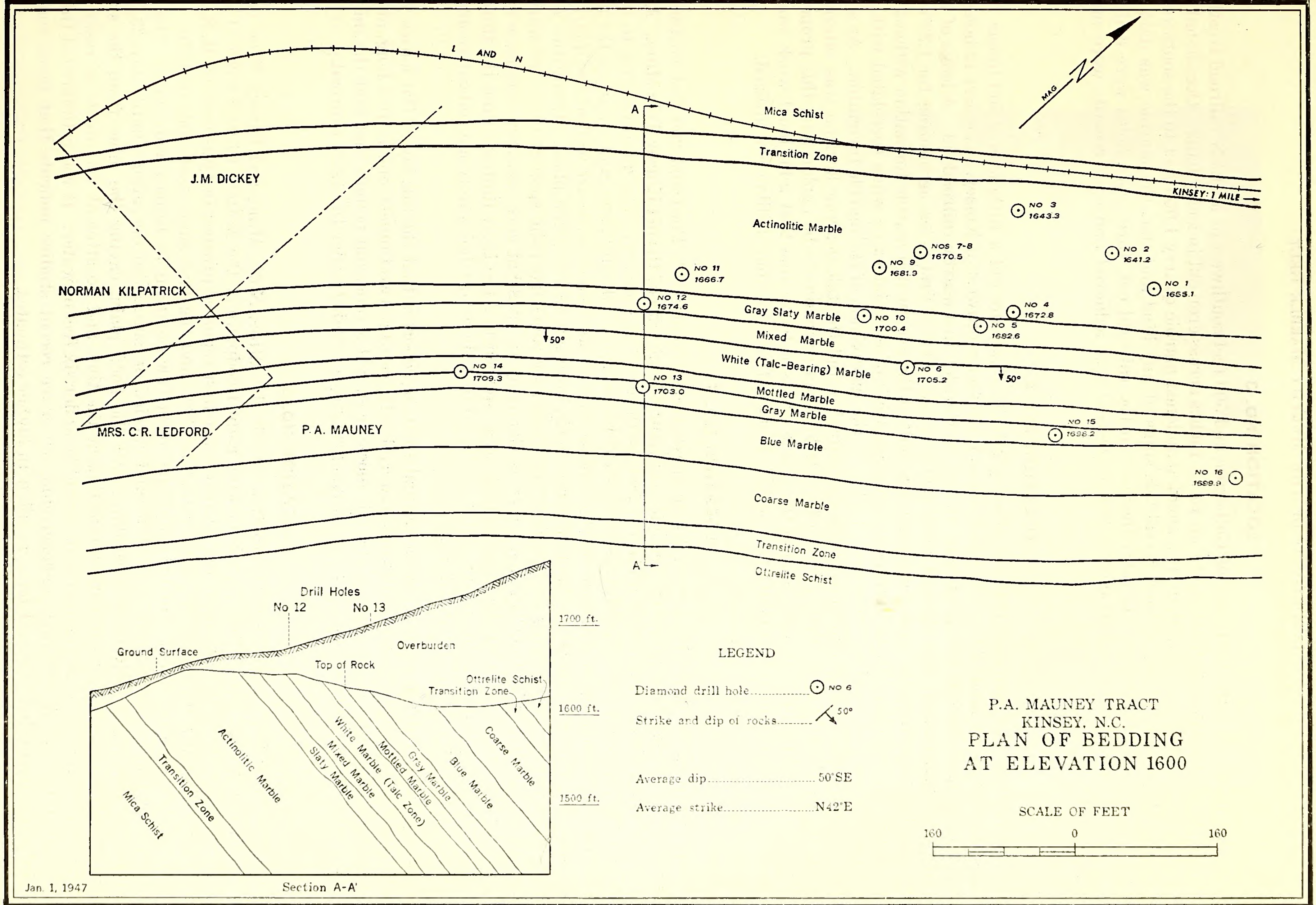
LOCATION NO. 1

In 1939 the Carolina Talc Company did core drilling work on the west bank of Rapier Mill Creek, 100 feet north of Georgia Highway 60 and about 500 feet north of the Georgia-North Carolina line. It is reported that six holes were drilled, encountering white and light gray marble and only a few small specks of talc. There are no outcrops in the vicinity to indicate the presence of talc. The property was core drilled because of the presence of a red soil that was considered indicative of talc. No core records were preserved.

LOCATION NO. 2

It is reported that several small shipments of talc were made from this property. The appearance at present is of a number of open pits, made apparently at random on the Cearly property in the bend of a clay road leading northwest from Culberson. Other than rare small talc scales and a light gray plastic clay, there is no evidence either of talc or marble.

[1] U. S. Bur. Mines, R.I. 3804, 1945.



CARTOGRAPHY BY TVA MAPS AND SURVEYS DIVISION

PLATE 1

LOCATION NO. 3

In a railroad cut, one mile northeast of Culberson and 500 feet southwest of an L&N railroad trestle over Rapier Mill Creek, talc lenses and stringers up to 18 inches across crop out in a clay bank. Occasional ledges of marble are exposed in the cut and there is a small abandoned marble quarry 1,000 feet to the southwest. It is reported that the marble quarry did not reveal talc signs of any kind and that the marble was dark gray, white, and multicolored. On the basis of talc exposures in the railroad cut, three core holes were drilled between the talc outcrops and the marble quarry but no success was achieved and core records were not preserved.

LOCATION NO. 4

In the fall of 1945 and spring of 1946 the Mauney Mining Company did a little over 2,600 linear feet of core drilling for talc on the land of P. A. Mauney, about 1,500 feet southwest of Kinsey. The first 12 holes were located from the appearance of talc fragments in the overburden in a nearby railroad cut. A ledge of tremolitic marble in the railroad cut also showed small scales of talc. These first holes, accounting for 1,875 linear feet, intercepted nearly all of the upper stratigraphic half of the overturned marble formation without showing more than an inch of talc. These first holes, however, were of especial value when correlated with information from other sources, and they represented a key to the subdivision of the marble formation. As a result of the newly acquired data, four additional holes were drilled and the talc-bearing horizon was intercepted, although no talc was found. More than 1,000 feet of strike length remains to be explored on this property to the northeast toward the old Kinsey Mine, and there is no reason to assume that additional work would be illogical if close geologic control is maintained and if the data from previous drilling are utilized.

LOCATION NO. 5

Near the southwest bank of the Nottely River, downstream from Hall's Ford and 300 feet northeast of Kinsey, an abandoned marble quarry now occupies the approximate site of the old Kinsey Talc Mine. A number of old caved shafts or pits can be seen for 100 feet southeast of the quarry. The quarry seems to include a small part of the white marble zone, full sections of the mixed zone and slaty zone, and a part of the actinolitic zone. One four-foot ledge of silicified marble can be seen on the caved southeast wall of the quarry and five lenses of talc, from three inches to twelve inches thick, crop out in the same place. Quantities of soft talc appear on the surface and in clay overburden, but these may come from the spoil of the older workings. Three core holes were drilled by the Cherokee Minerals Company in 1938 but core recovery was poor and no signs of talc were revealed. Two of the holes were located southeast of the L&N Railroad, and the third hole was on the northwest side nearer the quarry. It is believed that these core holes were not indicative and that additional prospecting would not be out of order.

When J. H. Pratt visited the Kinsey Mine around 1900, he reported that the talc lay in flat lenses wholly within the marble and associated with siliceous material. There were two tunnels, one 75 feet long, at levels 10 feet apart. Pratt reported that some of the talc blocks weighed a thousand pounds and that the mill produced six tons of "flower" talc per day. The workings probably extended under the L&N railroad.

LOCATION NO. 6

The Carolina Talc Mine is also known locally as the Bailey Mine, Notla Mine, and Kinsey Mine (not to be confused with Location No. 5). It is situated on the right floodplain of the Nottely River 3,000 feet northeast of Kinsey and 1,900 feet west of Rogers Chapel. The first reported prospecting was done by H. S. Predmore and/or the Binney and Smith Company around 1907-08, and the first shaft was sunk in 1916. From 1926 until 1934 the property was operated through the Notla Talc Company by Binney and Smith. The Carolina Talc Company took over the property in 1934 and carried on successful operations until July 23, 1938, when high water from the Nottely River spread out over the flood plain, caving the mine from the surface and flooding it. Hiwassee Dam was nearing completion at the time and no attempt was made to resume operations since the surface level at the mine soon would be under six feet of water. It was estimated at the time that about 25,000 tons of talc remained underground, but more recent studies indicate that more complete core drill information probably would have resulted in higher estimates.

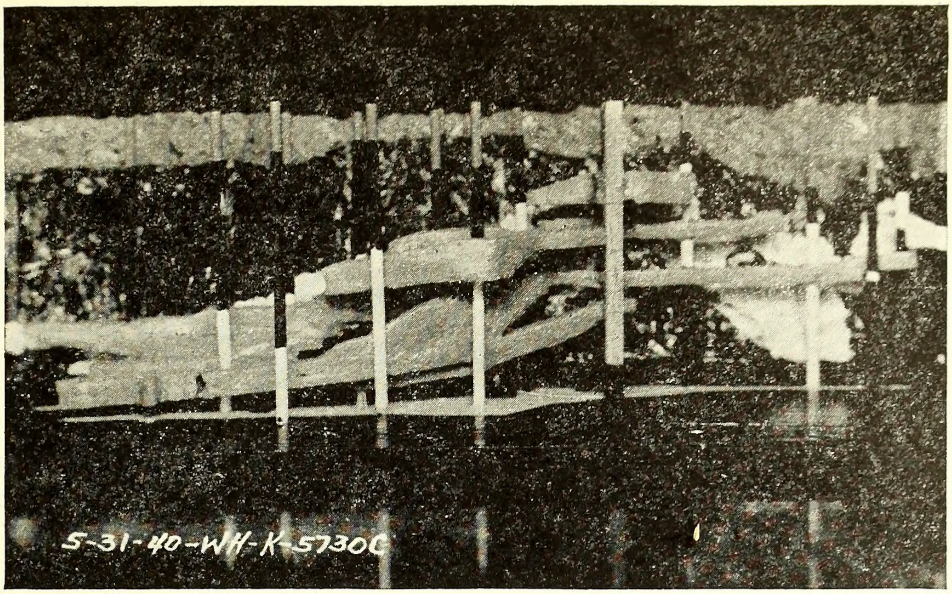


FIG. 7.—MODEL SHOWING UNDERGROUND WORKINGS AT THE CAROLINA TALC MINE. WHITE PARTS OF PEGS REPRESENT TALC ENCOUNTERED IN DRILL HOLES. LOOKING NORTHWEST.

Entry to the mine was by way of an eight by ten foot shaft, vertical for 116 feet, and then following the steep footwall to a total depth of 155 feet. Drift levels were opened from the shaft at the 56 foot, 82 foot, 104 foot, and 116 foot levels and combination drift-slope mining was carried on in both directions along the axis of the talc body. Talc was brought down from the roof and face by barring or by shooting with 40 per cent and 60 per cent dynamite, or a combination of both methods. Underground water flow from the nearby Notteley River caused potential hazards, and two bulkheads were required to hold back a nearly unrestricted flow through open cavities. Average water inflow during normal operations amounted to about 250 gpm, but maintenance facilities included three pumps rated at 2,500 gpm each for use during the rainy season. Two pumps of 3,585 gpm total capacity were held in reserve.

Crude talc was hoisted from the mine by an electric three-drum hoist having 14 by 24 inch drums. The talc was pulverized in a Bethlehem 4-roll crusher incorporated with an air separator having a capacity of 1,500 pounds per hour at 98 percent minus 200 mesh. Crayons were sawed with one block saw, one slab saw, and five finishing saws. Average labor for the mine and mill consisted of around 20 men. Drill cores at the Carolina Mine were logged only to differentiate talc and marble; the core records do not reveal the detailed mineralogy or structure which characterized the cores.

The talc deposit apparently was similar in size and general configuration to that at the Nancy Jordan Mine (Location No. 10), but there seems to have been a greater amount of mixed talc and marble and a less definite outline of a main talc body. The enclosing marble had a strike and dip of about N40°E, 55°SE; the talc plunged approximately 15° in a direction S25°W and dipped with the marble. Hangingwall and footwall structures were more evident than at other localities, and it is near the footwall particularly that a slate rock may have been partially serpentinized, according to older descriptions of underground conditions. Older reports indicate the probability that distinct lineations of cleavage intersections were important structures, with trends coincident with the plunge of the talc. In a manner similar to the Mulberry Gap deposit (Location No. 7), it is possible that the northeast end of the Carolina deposit has slumped vertically downward as a result of mass disintegration of the underlying marble. Associations of silicified marble around the talc, and as kidneys in the talc, were similar to associations in other talc bodies in the area, as was the presence of "mineralized" (pyrite, phlogopite, scapolite, actinolite,etc.) marble in those places where the talc normally might have been but specifically was absent.

The Carolina Mine supplied some of the finest quality talc ever produced in North Carolina. Standard grades of pulverized talc were supplied in large quantity and approximately 4 per cent of the talc was cut into crayons. Mr. J. W. Bailey, President, of the Carolina Talc Company, has graciously given the writer permission to publish the production and cost data in Table II. Production figures for the years prior to 1930 are not available. The Carolina Talc Company was solely an operating company for Notla Talc Company and thereby showed neither profit nor loss.

TABLE II

PRODUCTION AND COST DATA — CAROLINA TALC COMPANY

YEAR	[1]Crude Talc Produced	[1]Powder Produced	[1]Crayons Produced	[2]Mining Cost	[3]Grinding Cost	[4]Crayon Cost
1930	904	963	33	$ 10.45	$ 11.26	$ 118.59
1931	1,416	1,225	9	11.84	9.30	156.18
1932	1,221	1,183	38	9.95	7.94	62.47[5]
1933	1,474	1,191	58	7.47	5.77	151.70
1934	647	838	76	8.20	8.91	149.51
1935	1,301	1,586	53	9.91	6.22	257.55
1936	2,762	1,868	103	6.86	5.03	165.06
1937	1,545	1,621	96	16.60[5]	5.61	200.67
Total	11,270	9,575	466	$ 81.28	$ 60.04	$ 1,261.73
Average	1,490	1,193	58	$ 10.11	$ 7.50	$ 157.71

[1] Short tons.
[2] Per ton crude.
[3] Per ton powder.
[4] Per ton crayons.
[5] Very low and very high cost figures reflect differences in the degree of expansion in any single year. Variations tend to balance over long periods.
Note: Certain sales costs and incidental expenses are distributed thorughout these costs

LOCATION NO. 7

The Mulberry Gap talc mine is situated on marginal land of Hiwassee Lake and is licensed by the Tennessee Valley Authority to the Minerals and Metals Corporation, Murphy, North Carolina, of which H. G. Robinson is President, F. C. Bourne is General Manager, and J. W. Bailey, Jr., is Superintendent. The mine is located 2,500 feet northeast of the Carolina Mine and 1,400 feet northwest of Rogers Chapel, on the right bank of Nottely River. Older workings at the same locality have been called, at various times, the Hillyer Mine, the Munsford Mine, the Davis Mine, and the Old Mill Mine.

In 1900 J. H. Pratt described the mine as owned by the Atlanta Talc, Mining and Manufacturing Company, of which Judge George Hillyer, of Atlanta, Georgia, was President. There were three shafts, 100 feet apart along the line of strike, each shaft being 60 feet deep and penetrating the talc for 27 feet. "The footwall of quartzite is but 16 feet from the shafts and is dipping nearly 30° to the southeast. The width of the (talc) bed is known to be 40 feet . . . . A little to the northwest of the line of shafts and 300 feet to the southeast (southwest ?), a tunnel 100 feet long was run along the quartzite (silicified marble ?) contact and good talc encountered.

"This mine has yielded several thousand tons of the finest quality of talc, but practically none of it was compact enough to be used in cutting into pencils."[1]

It is reported that several later attempts were made to reopen the workings but water flow prevented success. H. S. Predmore began investigations sometime after 1940 and the property was taken over by the Minerals and Metals Corporation. Production began in 1944, but this new work did not involve the older openings which lay to the northeast and southeast.

Entry was made through an inclined shaft, down a vertical winze, then along a cross-cut and a drift within good white talc was opened to the northeast. In the meantime, a small stope was made near the vertical winze. Poor underground conditions halted work in the northeast-running drift and Shaft No. 2 was begun. Because of slow progress and a desire for more immediate production, Shaft No. 3 was begun and, by good fortune, it intercepted 26 feet of talc. Shaft No. 2 was continued and all three shafts were

[1] J. H. Pratt, 1900, p. 20

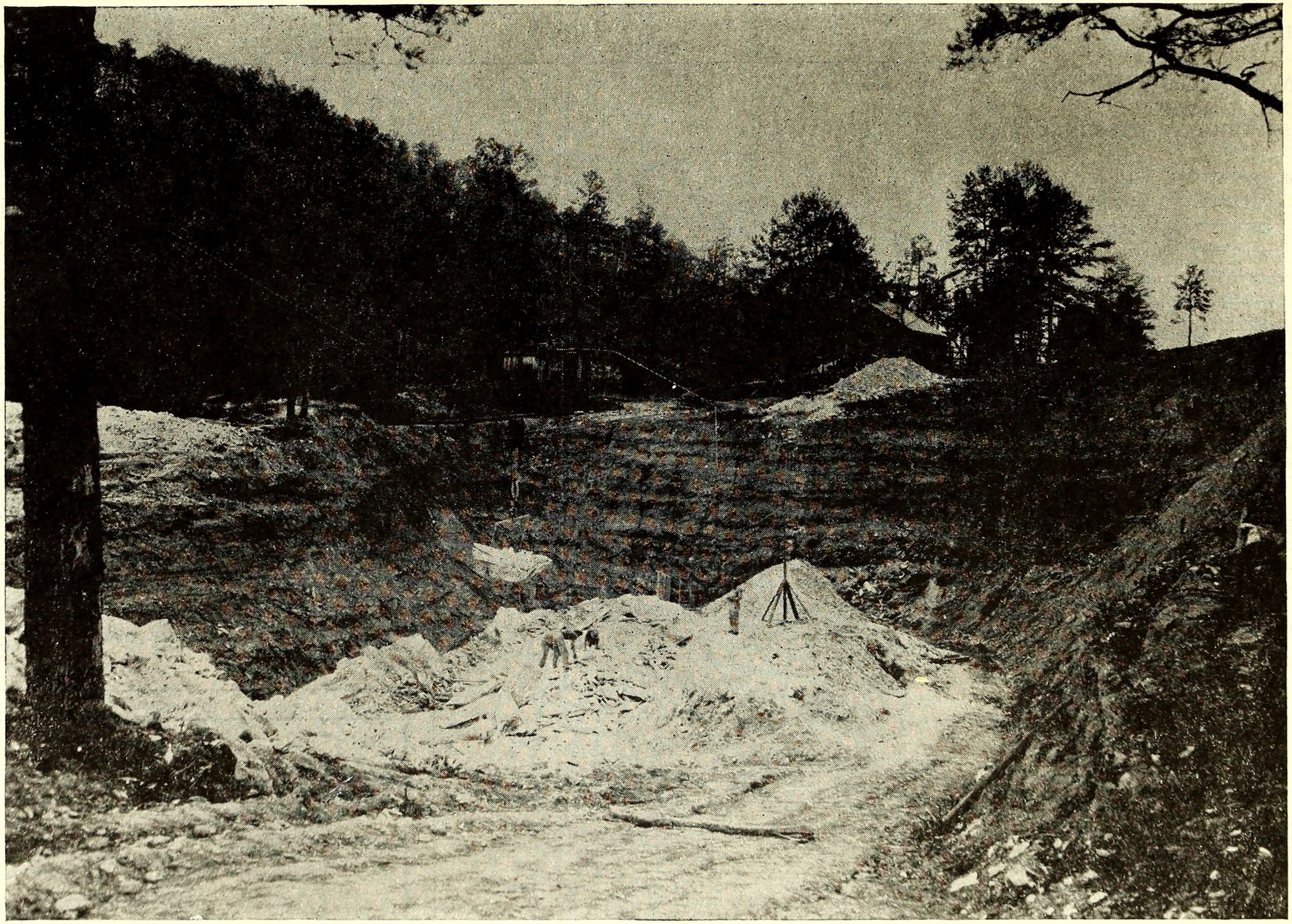
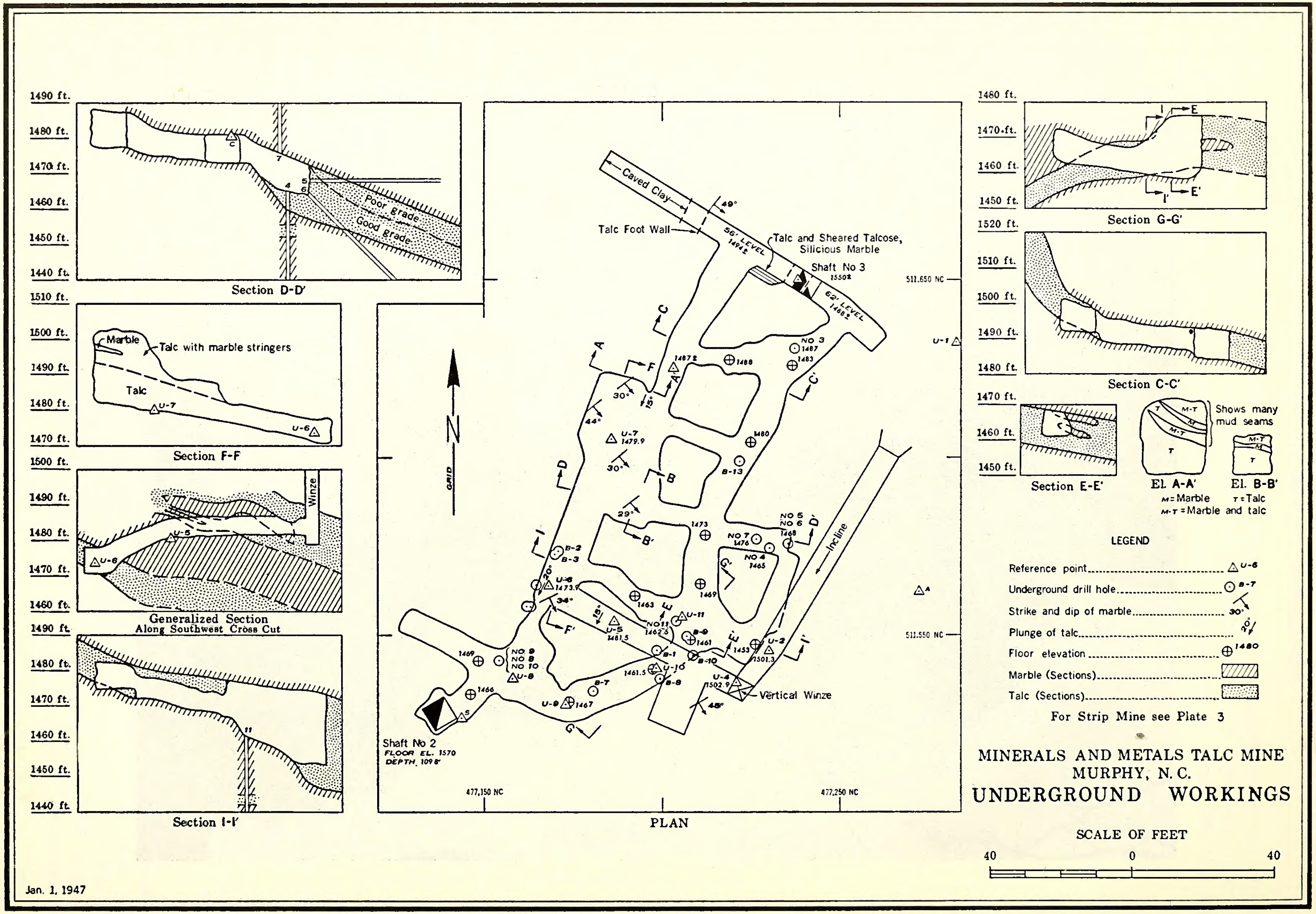


Fig. 8.—Mulberry Gap Strip Mine, Looking Southwest. (Photo Courtesy Minerals And Metals Corp.)



CARTOGRAPHY BY TVA MAPS AND SURVEYS DIVISION

PLATE 2

subsequently connected by drifts and crosscuts. A small crosscut was made to the northwest near Shaft No. 2 and intercepted a steep, six-foot body of talc that was too badly clay-stained for use at that time. All this work was done under the managership of W. O. Hoffman and later under George S. Stauning.

Underground conditions became uncertain and a study of the structure indicated the possibility that the southwest-plunging talc body would be accessible from an open pit to the northeast. A series of 12 core holes were drilled and plans were formulated to make a pit 110 feet long by about 55 feet wide, involving some 23,000 cubic yards of earth excavation. Excavation has now been completed and successful open cut mining is underway. An estimated 15,000 tons of talc will be available through this phase of the operation. Current plans call for a later extension of the open cut work to overlap the older operations, and the newer underground openings will be re-entered.

Approximately 1,700 tons of talc were removed from the underground openings. Crayon talc was sawed at the company's own mill in Murphy and the powdered talc was, and is, custom ground by the Hitchcock Corporation near Murphy. The talc is of average grade, having a color rating of from 87 to 93 per cent of the whiteness of standard magnesium carbonate. The upper portion of the talc in the open pit has badly stained areas but better quality is encountered with increased depth.

The absolute configuration of this talc body is not known, although it is certain that structural and mineralogic tendencies are nearly identical to the other talc deposits of the area. Minimum length and width in places are 300 and 100 feet, but the average thickness is about 10 feet, less than either the Carolina or Nancy Jordan deposits. All of the exposed wall rock is more or less silicified, as are the rock "kidneys" inside the otherwise pure talc, but quartz-free marble lies a short distance away. It is probable that the northeast end of the talc body has slumped because of disintegration of the dolomitic marble which supported it. This slump gives the initial impression that the talc has a double plunge (Plate 3).

LOCATION NO. 8

This property is owned by the Tar Heel Investment Company of Asheville, North Carolina. It is situated near Sneed Branch, two miles southwest of Murphy and 4,500 feet northeast of the mouth of Cane Creek. A number of pits have been dug along an old logging road, and white talc shows at the surface in several places. It is reported that two or three tons of talc have been removed from the pits. Although no definite evidence is present, it is possible that the talc has been transported by creep and that a normal outcrop position would be several feet to the southeast.

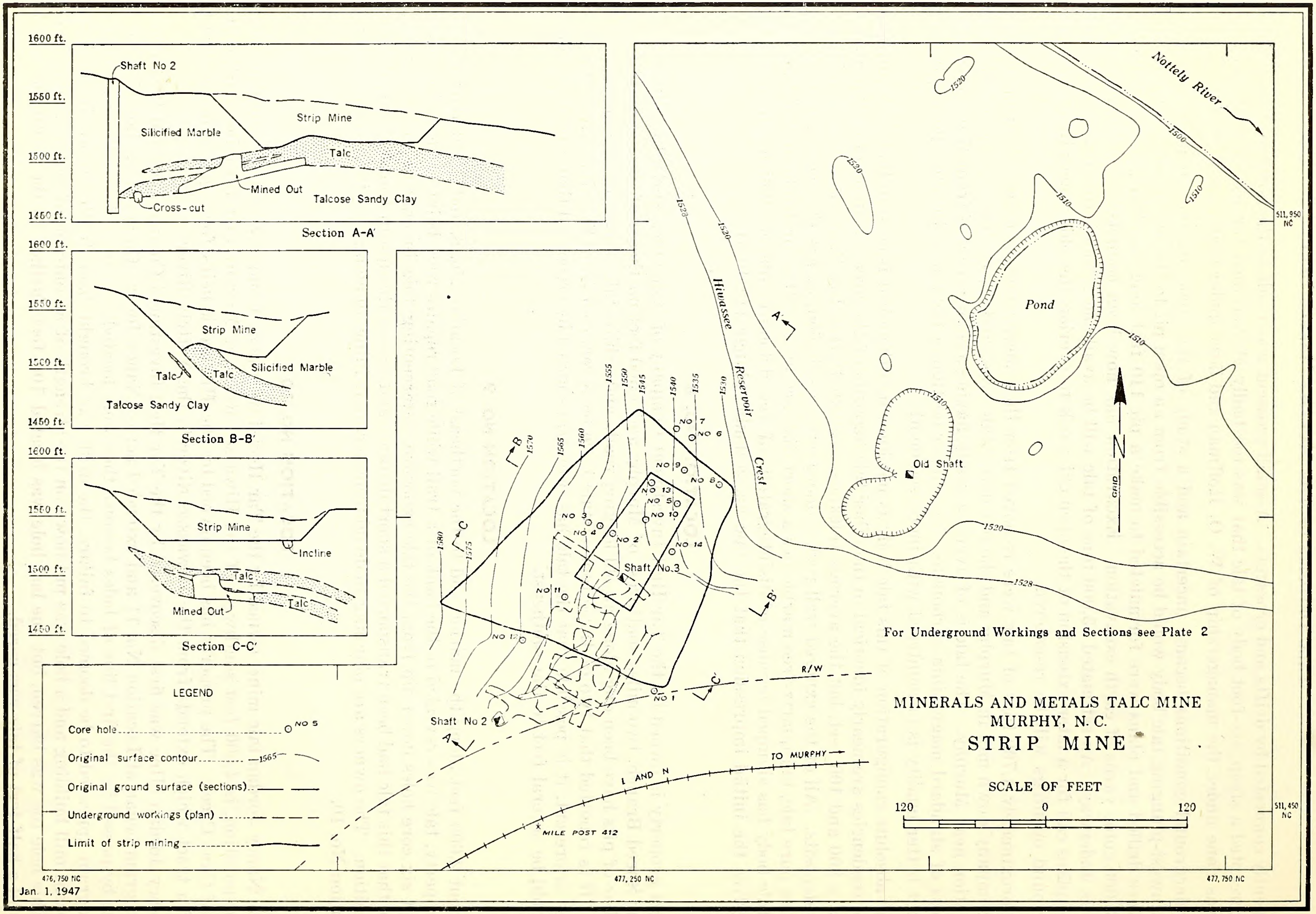
LOCATION NO. 9

About 2,600 feet along the marble and to the northeast of Location No. 8, and situated on the same Tar Heel property, talc was revealed in the bank of a trail while road repairs were being made. The owners drilled about six core holes down dip from the talc exposure, intercepting talc in only one of the holes. It is possible that this talc had been transported a short distance and was on the up-dip (northwest) side of the outcrop position. The owners are planning to do additional core drilling all along the strike from Location No. 8 to Location No. 10.

LOCATION NO. 10

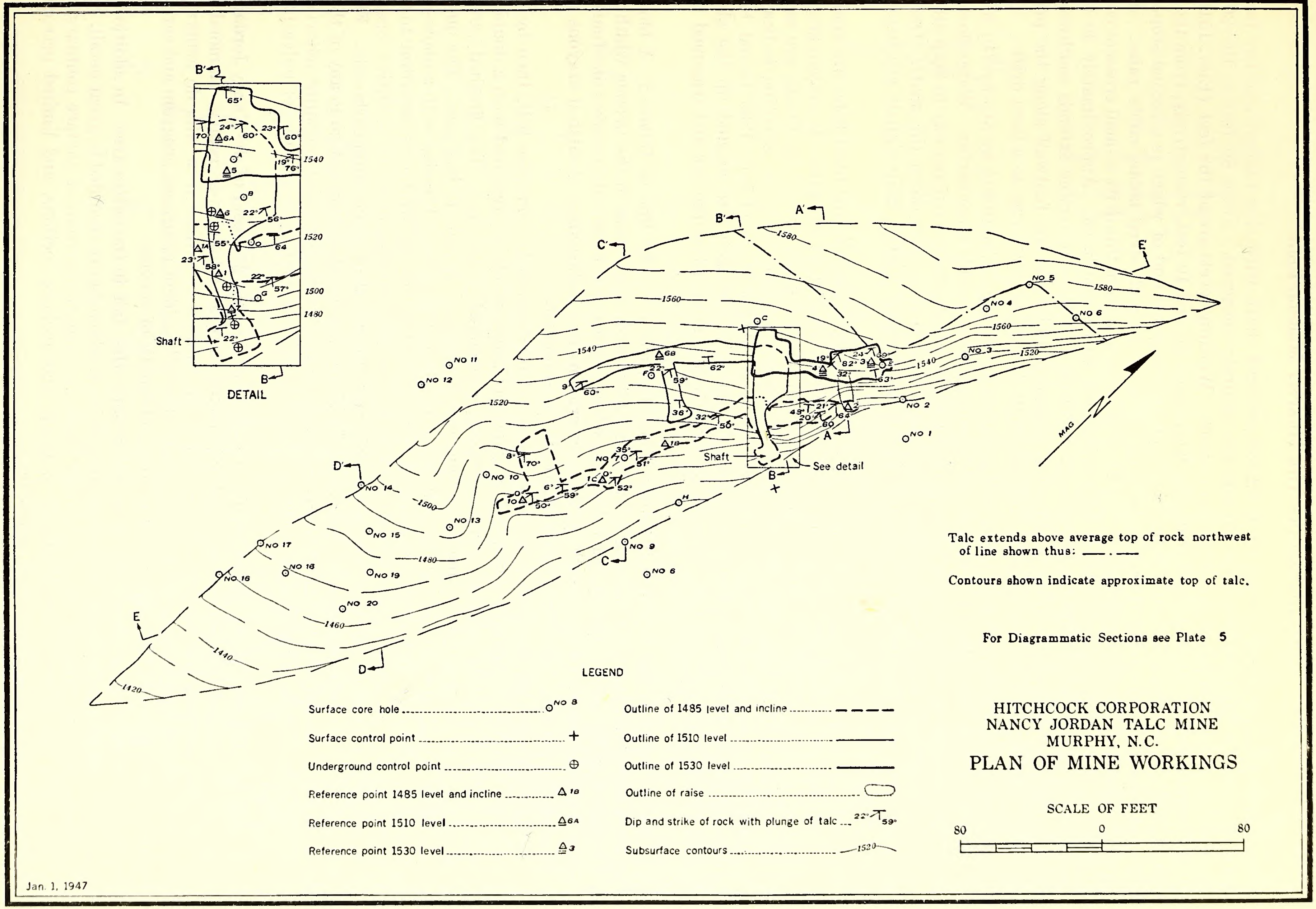
The Nancy Jordan talc mine, owned by the Tar Heel Investment Company and operated by the Hitchcock Corporation, is 4,500 feet southwest of the Hiwassee River at Murphy and 1.9 miles northeast of the mouth of Cane Creek. The property has been owned by the Hitchcock heirs for a great many years, being part of a tract which extends from the Hiwassee River to the Nottely River.

Nancy Jordan Mine was first discovered by the Tar Heel Investment Company around 1941 when a core drill program began at Location No. 11 and extended across Nancy Jordan Gap to about Location No. 9. The site was by-passed by the first line of holes because they were located too far to the northeast. When the entire program appeared to be doomed to failure, the drill was brought back to the approximate location of the present mill building and a hole was put down on the strength of an outcrop of sandy marble in the road bed. This hole too was barren, but one last hole was located 100 feet farther to the southeast and twenty-three and a half feet of talc was cored.



CARTOGRAPHY BY TVA MAPS AND SURVEYS DIVISION

PLATE 3



CARTOGRAPHY BY TVA MAPS AND SURVEYS DIVISION

PLATE 4

The mine shaft is a two compartment, 10 by 12 foot collared shaft, with ring timbers and two inch lagging extending to the 80 foot level where the timbers are securely anchored. From 80 feet to the 208 foot bottom the shaft is in solid marble and requires no support. Working levels are at 168 feet (Elev. 1513) and 196 feet (Elev. 1485) where crosscuts enter the talc body about 20 and 10 feet, respectively, from the shaft. A stope on the 1513 level gives access to the 1530 level, at the northeast end of which is a second stope. The 1530 stope is connected to the northeast end of the 1485 drift by a small, steep ladder-chute raise. A drift extends southwestward from the main crosscut on the 1513 level and from this drift a small crosscut connects the main talc body with several large pockets of very white talc to the southeast. Approximately 40 tons of talc has been mined from these pockets to date. From the 1485 foot level an incline extends southwestward down the plunge of the talc body with the incline floor generally following the footwall along the principal axis of the body. After reaching an elevation of about 1440 the incline gives way to a level drift.

All stopes and some of the drifts are square-set in an excellent manner, with 5½ by 5½ by 7½ foot sets using 7 by 9 inch pre-cut oak timbers, and thus far there has been no trouble from caving. Water flows come almost entirely from surface drill holes. A 170 gpm pump operates about one hour per day to keep all sumps at safe levels. All underground lighting is by electricity with conduit entries down the shaft. Operating signals between shaft head and mine are made by blinking the electric lights. Skip signals are made by a hand-pulled bell cord.

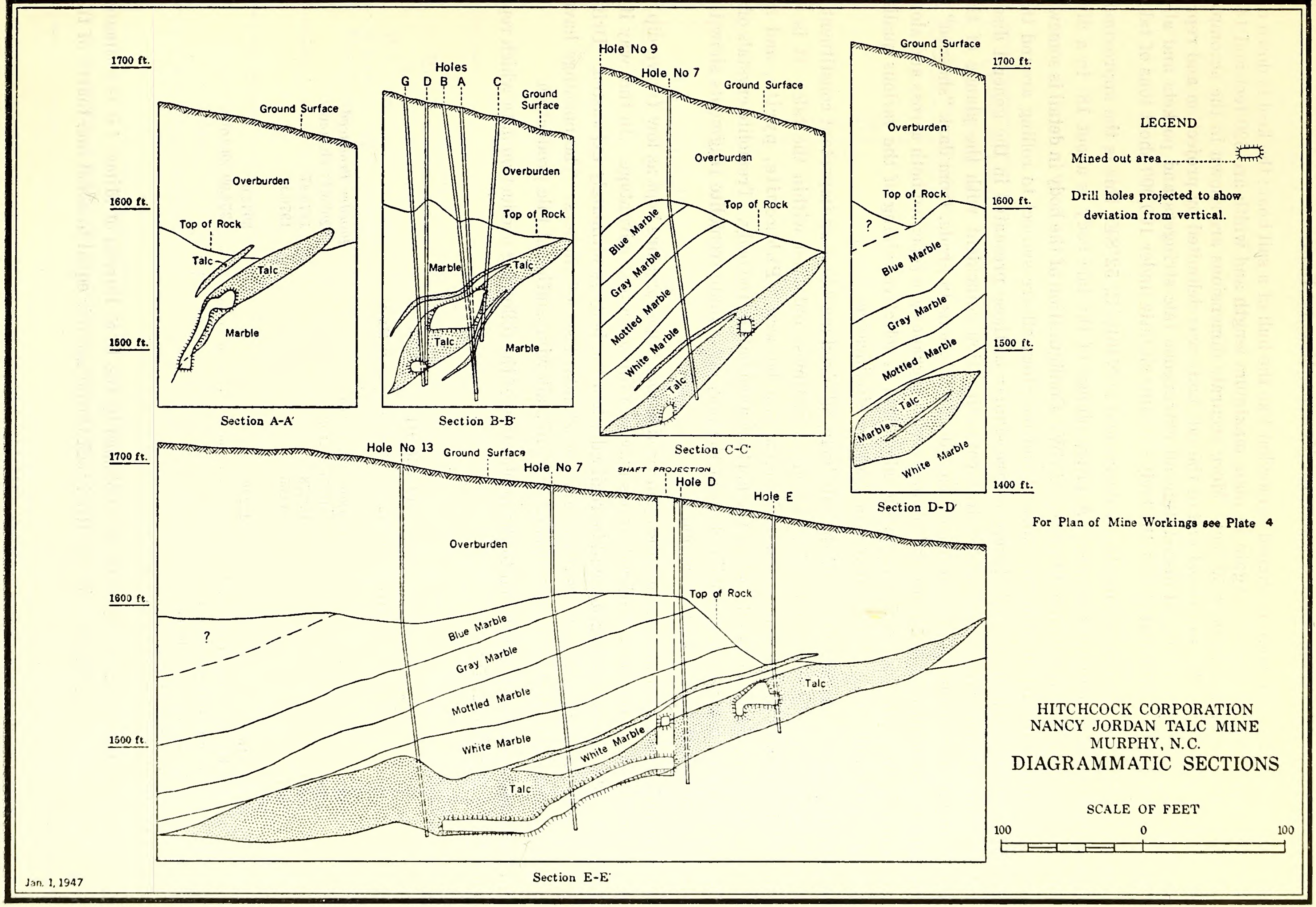
A sullivan air operated post core drill is used for underground exploration, and blast holes are made with stoppers and jackhammers. The necessary shooting is done with Special D. explosive. In crayon grade talc, as large blocks as possible are dropped on a pad of fine talc to prevent splitting and the blocks are sawed to handling size with an ordinary two-man cross-cut saw. In talc of pulverizing grade, shooting is heavier to produce as good fragmentation as possible. Talc is shoveled or placed by hand into 1200 pound buckets, which in turn are trammed to the shaft on hoist-operated flat cars. Buckets are hoisted up the shaft by means of a steam hoist converted to air, and the talc is dumped into a tilt-dump car and trammed to storage bins.

Crayon talc is chuted to the crayon mill where it passes through a saw line as follows: A block saw cuts to handling size and establishes the length of the crayons; a slab saw cuts to the proper width; finish saws end the operation by giving the correct thickness; when necessary, a dowel cutter makes one-fourth inch round pencils from one-fourth by one-fourth inch square crayons five inches long. Finished crayons go successively to graders, packers, and craters and are ready for shipment.

Pulverizing talc goes from the storage bin to a primary hammer mill by conveyer belt, then by belt to a 10-ton feed bin. The talc is then delivered to a Raymond roll mill which is integrated with a double whizzer air separator, all in closed circuit and feed controlled by pneumatic pressure. The finished powder is placed in 50 pound paper bags by a two-tube Bates Bagger and trucked one mile to box cars. The quality of the finished product is controlled by taking bag samples at half-hour intervals and testing with a photo-electric comparator against standard magnesium carbonate. Grading is by color and whiteness according to the ICI tristimulus filter system of the National Bureau of Standards. By blending different qualities, operations are based on a standard product having a whiteness rating of 90 per cent of magnesium carbonate. Fineness of grind is checked with a Hageman gauge. Talc from the Nancy Jordan Mine does not go to any of the economy markets, but is used principally for crayons, cosmetics, textile bleacheries, rice polishing material (grit free) and similar grades. It is believed that this talc has excellent opportunities for uses of pulverized talc in ceramic industries.

F. C. Bourne is Treasurer of the Hitchcock Corporation and General Manager of the Nancy Jordan Mine. J. W. Bailey, Jr., is General Superintendent. Other personnel are a technician-secretary, diamond driller and helper, six mine workers and sixteen mill employees, in addition to several men who do general work around the plant. The company sponsors an employee health and accident insurance program and carries out a bonus system based on safety, attendance, production, and length of service.

More is known of the Nancy Jordan talc body than of any other talc in the entire area. In addition to the underground work, there are 23 fairly well-spaced core holes of which 14 are recorded in great detail. Studies included examination of core records, survey of mine openings, and preparation of surface contours, top of rock contours, top of talc contours, talc thickness contours, and geologic sections, and limited petrographic work. Partial chemical analyses were also available.



CARTOGRAPHY BY TVA MAPS AND SURVEYS DIVISION

PLATE 5

In plan-projection, the talc body is shaped somewhat like the hull of a sail boat; the keel is down dip and slightly down-plunge from the center. Again in plan, maximum length and width are 690 feet and 144 feet, and maximum vertical thickness is about 50 feet. More accurate dimensions are shown in the accompanying drawings. (Plates 4 and 5). The southwest end of the talc body was delimited by projection and represents a probable minimum. On this basis and discounting all extraneous talc stringers and pockets and all zones of mixed talc and marble, it is calculated that the body contains slightly under 100,000 short tons of talc.

The average strike and dip of the marble underground is N40½°E, 52°SE; this is the approximate average strike and dip of the talc layers as well. Average plunge of the talc body is about 18° in a direction S22°W, but the overall plunge is 14° in a direction S25°W. Configuration of the body in detail is somewhat irregular, since the plunge is variable and the footwall and hangingwall are subject to rolling around the long axis of the body. The principal internal structures are similar to those presented in the general discussion of talc bodies. Two distinct cleavages intersect to form a lineation coincident with the plunge of the talc body, contributing in part to the fibrous nature of the talc. Variations in grade, from dark "sheened" talc to good white talc, are controlled by both dip and plunge, and talc grades are repeated both across and along dip, strike, and plunge. These changes make feasible good control in selective mining of the various qualities as desired. Joints and faults have little economic or geologic significance.

Beginning half-way down the plunge of the talc body, silicified marble is an important constituent of the wall rock and of the small marble "kidneys" which are sometimes contained within the talc. It is in this siliceous material that most of the tourmaline in the mine can be seen. Phlogopite, pyrite, and smaller amounts of quartz are contained in wall rock of the northeastern half of the body. Tremolite crystals of megascopic sizes are not often found in or immediately near the talc, but minute tremolite fragments show in some of the talc when observed under the microscope.

Mining methods are aimed at maximum crayon production. Openings are kept as low (down dip) within the body as possible in order that overhead stopes may be utilized to best advantage. In this way it is expected that nearly 100 per cent extraction will be realized when the body is ultimately exhausted. Drifts and crosscuts have been maintained at a size suitable for one standard set of timbers. The openings have been designed to give maximum development information while allowing sufficient talc production.

Mr. F. C. Bourne has kindly consented to the publication of the following production data which represent total production to June 30, 1947:

TABLE III

TALC PRODUCTION — NANCY JORDAN MINE

Year	*Crayons Produced*	*Powder Produced*
1945a	200.65 sh. tons	2080.43 sh. tons
1946b	152.78	1875.47
1947c	69.55	1976.11
Total		
29 Months	422.98	5932.01
Total Production (29 months)		6354.99 sh. tons

a. February-December
b. January-December
c. January-June

Based upon production figures for 1946, as published by the U. S. Bureau of Mines, [1] it is estimated that the present average crayon production of the Hitchcock Corporation is equal to about one-fourth of the total United States production.

[1] U. S. Bur. Mines, Mineral Market Report, MMS. no. 1544, 1947.

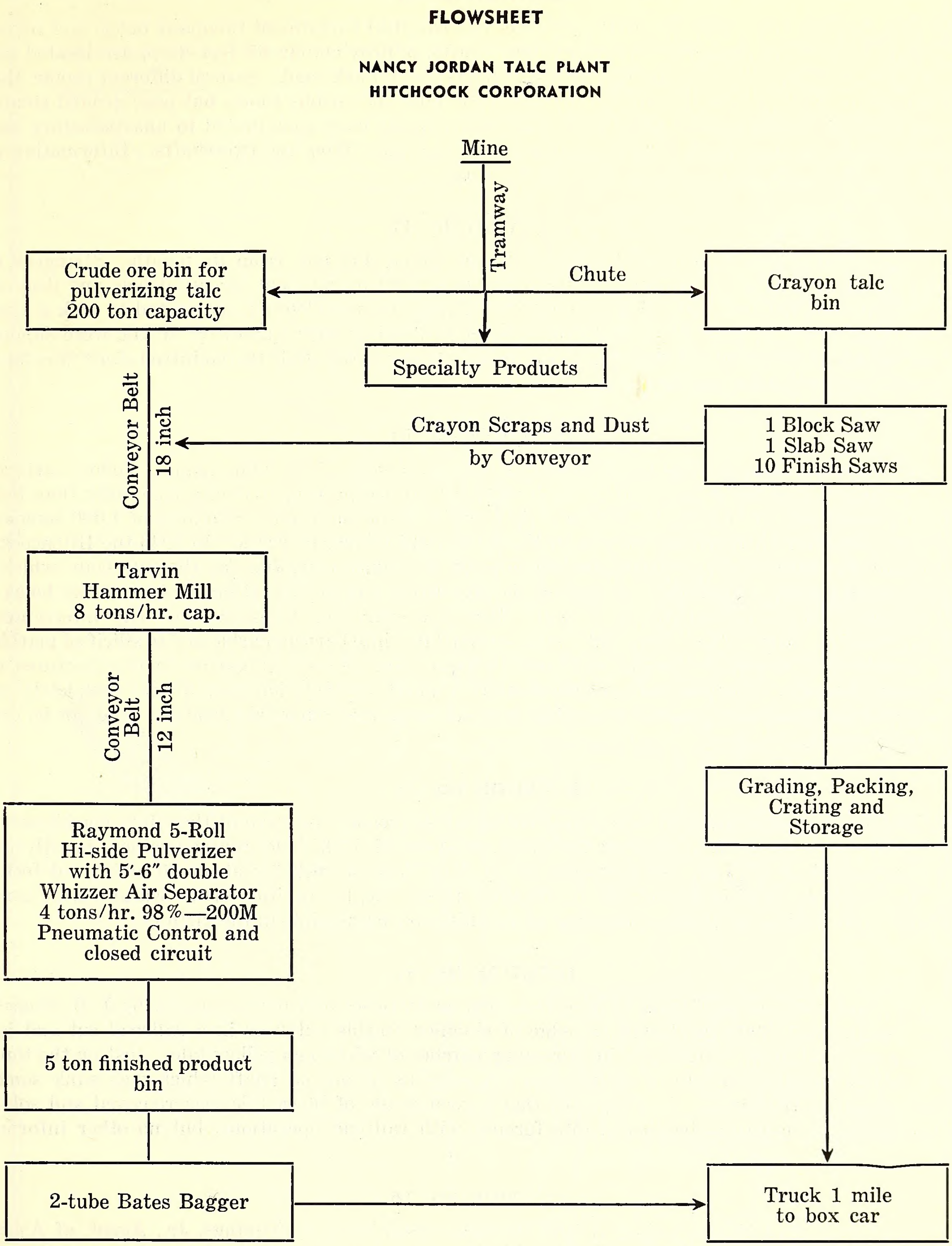

FLOWSHEET
NANCY JORDAN TALC PLANT
HITCHCOCK CORPORATION
Mine
Tramway
Chute
Crude ore bin for pulverizing talc 200 ton capacity
Crayon talc bin
Specialty Products
Conveyor Belt
18 inch
Crayon Scraps and Dust by Conveyor
1 Block Saw
1 Slab Saw
10 Finish Saws
Tarvin Hammer Mill 8 tons/hr. cap.
Conveyor Belt
12 inch
Grading, Packing, Crating and Storage
Raymond 5-Roll Hi-side Pulverizer with 5′-6″ double Whizzer Air Separator 4 tons/hr. 98%—200M Pneumatic Control and closed circuit
5 ton finished product bin
2-tube Bates Bagger
Truck 1 mile to box car

FIGURE 9

LOCATION NO. 11

The Cold Springs Mine was formerly owned by the Tar Heel Investment Company but is now owned by the TVA as a part of Hiwassee Reservoir land. Two shafts, approximately 65 feet deep, are located one on either side of a gravel road at the junction of the Murphy Town Park road. Several different people, the last of whom was F. C. Bourne, have attempted to operate the mine at various times, but poor ground conditions and excessive water, together with insufficient exploratory work, have contributed to unsatisfactory results. It is reported that a total of about 1,000 tons of talc has been taken from the two shafts. Information about the geology underground is too conflicting to report here.

LOCATION NO. 12

Small quantities of talc crop out in the bed of Valley River, 400 feet from its mouth. Stringers up to three inches thick are contained in dense, white, finely tremolitic marble, but stream debris and deep water prevent further observations. Mr. Harry Quintrell, of near Jasper, Georgia, attempted to sink a shaft in the peninsula between Hiwassee River and Valley River, and fairly large quantities of talc were supposedly intercepted before excessive water flow halted the work. It is believed that the Quintrell shaft was 30 to 35 feet deep and that production was never achieved.

LOCATION NO. 13

This prospect is known as "Section 6," being on a tract of land of the same name. Yellow surface talc has been recognized here for a great many years although no prospecting has been done other than the digging of a few small pits and trenches. Stained talc appears at the surface over an area of 1,000 square feet, and siliceous, tremolitic boulders may be seen in the fields and in a nearby creek. In 1946 the Hitchcock Corporation obtained a lease on the property for the purpose of diamond drilling for the talc body which supposedly furnished surface indications. A total of six core holes was drilled, although two of the holes were abandoned shortly after intercepting top of rock. The four completed holes satisfactorily intercepted the normal talc-bearing zone where the rock was confined to white barren marble and to silicified marble and zones of considerable tremolite. One of the holes disclosed thin veinlets of galena in the fractures of an otherwise pure dolomite. Correlations indicate that the original talc body has been almost completely eroded and that only transported talc can be seen. This does not mean that other talc deposits could not be present a short distance away.

LOCATION NO. 14

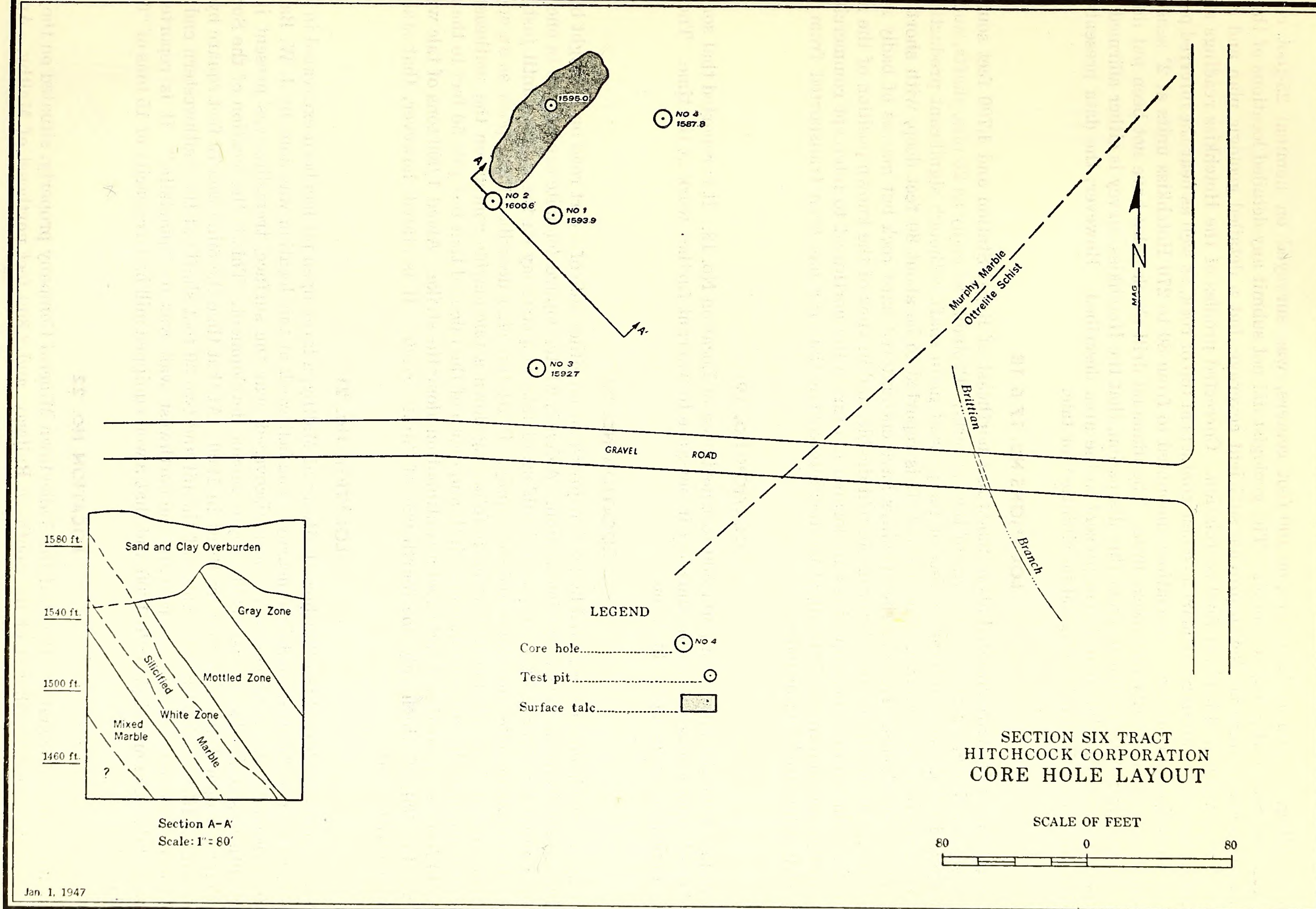
This location is noted because of data which indicates the probable position of the white marble zone in a concealed area. A churn drill, in drilling for water, intercepted dark, blue, coarse-grained, heavily graphitic marble at a depth of 105 feet, and continued in the same type of rock for about 40 additional feet. By applying the principle listed in the section on prospecting for talc, the position of the white marble zone can be calculated. No indicative surface outcrops of any kind are perceptible in the vicinity.

LOCATION NO. 15

Forty-six hundred feet southwest of Regal Station, on property now owned in part by J. B. Moore, and in part by the Southern Railway System, a ledge of silicified marble outcrops in a railroad cut and is surrounded by a clay residuum which contains irregular patches of white and yellow talc. Just on the top edge of the cut, nearly opposite Mr. Moore's house, are the remains of an old shaft which was sunk sometime around 1900 by a Mr. Heighway. It is reported that a good grade of block talc was removed and sold, and that the operations were stopped because of interference with railroad operations, but no other information is known.

LOCATION NO. 16

Overlapping Location No. 15, a block of land has been leased by J. P. Jennings, Jr., Agent, of Asheville. On the basis of the data listed under Location No. 15 above and of a general knowledge of the position of the Murphy marble, the lessee conceived a plan to make a geophysical survey over a test area and check results



CARTOGRAPHY BY TVA MAPS AND SURVEYS DIVISION

PLATE 6

by diamond drilling. A total of 12 ranges, on 100 foot centers, was surveyed on nominal 25-foot centers, using a Hotchkiss Super Dip magnetometer. The geologist did not submit any detailed locations of the geology, except those which were needed to provide sufficient coverage, but a detailed geologic plan and section was prepared in advance and held for final correlation. Corrected profiles of the Hotchkiss readings showed distinct anomalies near the inferred marble-schist contacts at top of rock, as well as near the inferred position of the silicified white marble zone. Variations amounted to from 80 to 270 Hotchkiss units at 2° sensitivity setting, with a base norm of 125 Hotchkiss units. The diamond drill check holes have not been put down at this time. It should not be assumed, from this discussion, that the Hotchkiss survey is either affirmed or denied, nor is it inferred that talc is or is not present in the area described. However, the data presented under Location No. 15 are indicative of good possibilities for talc.

LOCATIONS NO. 17 & 18

The Regal Talc mines are situated about 2,500 feet northeast of Regal Station and 4,700 feet southwest of Tomotla School. Lovat Frazer is in charge of the property. Probably as many as 25 pits, shafts, and adits have been opened within several hundred feet of the present main shaft, although significant production has not been realized so far as is known. The main shaft is reported to be about 80 feet deep, with short drifts branching out at two levels. None of the openings have encountered hard rock but masses of badly stained talc were found. From the meager information obtainable, and in view of the known position of the marble formation, it is believed that these openings are located too far to the northwest to intercept commercial talc in good quantity, and that most, if not all, of the talc intercepted thus far has been transported from a few feet to possibly a hundred feet or more.

LOCATION NO. 19

Several pits have been dug at a point 500 feet northeast of Location No. 18. It is reported that some talc was found but it apparently was not of sufficient importance to warrant further work at the time. There are no surface indications present at this time.

LOCATION NO. 20

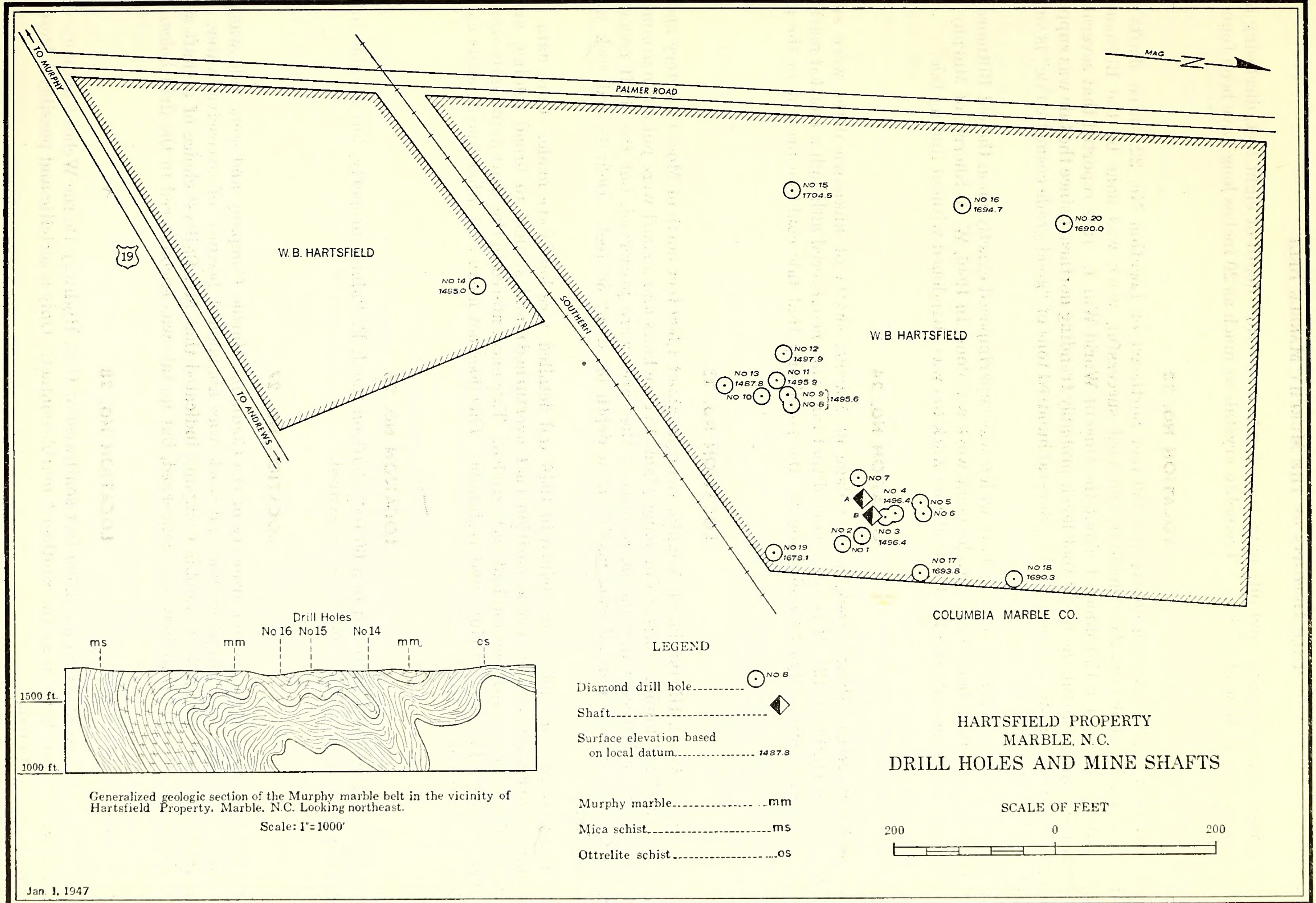
The Hayes Mine is now represented by large depressions on either side of a dirt road on the right bank of Valley River at the Tomotla stream gaging station. A dense, white, impure dolomite can be seen in one of the depressions and on the river bank nearby, and boulders of talcose quartz lay on the surface until just a few years ago when student collectors exhausted the supply. Pratt (op. cit.) described the deposit as an open cut about 60 feet long, 40 feet wide and 30 feet deep, following down a talc-marble contact on the southeast side. He stated that borings showed considerable width and depth of the talc and that test pits 50 feet to the southwest and 200 feet to the northeast indicated a continuation along the strike. About 1,000 tons of talc were removed prior to 1900, of which only one-fourth was of "first" grade. It is stated, however, that stain and grit decreased with depth.

LOCATION NO. 21

On the northwest side of the Southern Railway at Maltby, a large open pit has been excavated in search of talc and several core holes were drilled nearby. The last work at this location was done by J. W. Bailey in 1939-1940. Although considerable talc has been discovered near the surface, tremolite was present in such copious quantity as to render impracticable any economic development. This is the location of the Southern Mineral Company operations described by Pratt in 1900. At that time the mine was 70 feet square by 10-20 feet deep, with a 15 foot shaft at the center of the pit and two 30 foot shafts at the southwestern end of the pit. The southeast talc wall was of marble and the northwest wall was of "quartzite." It is reported that 1,000 tons of talc were mined prior to 1900 and that a well-equipped mill had a capacity of 15 tons of "flower" talc per day.

LOCATION NO. 22

This, apparently, is what Pratt called the Valleytown Mineral Company property, situated on the southwest side of a dirt road, northwest of the Southern Railway, and 2,800 feet northeast of Maltby. Approxi-



CARTOGRAPHY BY TVA MAPS AND SURVEYS DIVISION

PLATE 7

mately 200 linear feet of trenches and pits have been dug to an average depth of eight feet, disclosing heavily tremolitic talc similar to that at Maltby. Tremolite crystals as much as 20 inches long have been found here.

LOCATION NO. 23

Across the dirt road mentioned above, and 350 feet northeast of Location No. 22, three shafts of unknown depth have been sunk for talc. The first, and most successful, work was done by the Biltmore Talc Company, of Asheville, North Carolina, at about the time of World War I. It is reported that several drifts opened from the shaft at about the 60-80 foot level, probably trending northeast since the talc was supposed to have plunged northeastwardly at a low angle. Several hundred tons of "good grade cosmetic talc" is supposed to have been taken from the mine.

Around 1940, W. O. Hoffman sunk a shaft which was superimposed exactly upon the old Biltmore shaft, but operations were stopped before any development work was done. In 1946, W. A. Sherril, of Murphy, began a shaft to the north of the Biltmore location but this work too was abandoned without finding talc.

LOCATION NO. 24

About 600 feet west of Hyatt Creek, in the village of Marble, shafts of unknown dates were sunk on either side of U. S. Highway 19. It is not reported that talc was encountered although a mottled marble outcrop under the trestle across Hyatt Creek indicates the possibility that talc could be present in the general area.

LOCATION NO. 25

On property of W. B. Hartsfield, of Atlanta, Georgia, about 1,500 feet north of Moss Cemetery and 1,500 feet southwest of the Columbia Marble Company plant, 13 core holes and a shaft were put down around 1944. The drill holes did not intercept talc and no records of the cores were preserved, but the shaft encountered boulders of talc, tremolite, and siliceous marble at a depth of about 55 feet. Definite bed rock was not found in the shaft.

Several additional core holes were drilled in 1946 and detailed core logs were made. Core data showed that the marble formation was in normal position (not overturned) and subject to broad folding, and that any original talc at the specific location had been eroded. Talc encountered in the shaft apparently was transported material contained in alluvium and residuum. This does not mean that other talc deposits could not be in place in the general vicinity.

LOCATION NO. 26

It is reported that talc was found in a 66 foot shaft on the J. F. Palmer property, but reliable information about the general conditions could not be secured.

LOCATION NO. 27

J. W. Bailey put down a shaft on property of the Columbia Marble Company and some talc was found, but the shaft was located in swampy ground and work was abandoned because of excessive water. Later diamond drilling for marble by the Columbia Company indicated that Mr. Baileys' choice of a shaft site was logical so far as the marble's lithology was concerned, but no talc was encountered in the drill holes.

LOCATION NO. 28

On Junaluska Creek, at Andrews, 3,500 feet southwest of U. S. Highway 19, the Weber Company, of New York, put down several shafts near the southeast marble contact. Only a sericitic and possibly talcose, black and green slate was found.

LOCATION NO. 29

Shallow pits and inclines were put down in a marble outcrop on property of the Nantahala Talc and Limestone Company, 250 feet northeast of the mouth Jenkins Branch and 2,700 feet west-southwest from Topton School. By hand-working small (12-18 inch) pockets, some talc was removed before water flow and a lack of adequate equipment brought the work to a halt. Other digging was done in talcose sericite schist.

LOCATION NO. 30

About 1,000 feet northeast of Location No. 29, development work was only slightly more extensive and successful. Talc pockets contained in a strongly sheared marble produced some low grade talc, mostly quite dark. The marble is less than 100 feet thick here, so that any further exploration work would be restricted to a small area.

LOCATION NO. 31

Just to the northwest of U. S. Highway 19, 400 feet southwest of the Macon County line and one mile southwest of Nantahala Station, a small talc body was discovered and mined by the Nantahala Talc and Limestone Company. The strike and dip of the marble are N32°E, 70°SE. The talc plunged about 30° to the northeast. Silicified marble, with additional quartz in the form of rounded sand grains, is in clear evidence on either side of the talc body and for 100 feet or so along the strike as well. The talc body was about 30 feet long and 6 feet wide and about 4 feet thick in the larger sections, thinning to a few inches up and down the dip and along the plunge. It apparently contained many marble inclusions. The talc was of good clear color, somewhat sheared, and exhibited curved grain and very hard, glazed surfaces. Additional work has not been done since the bulk of the small talc body was removed.

LOCATION NO. 32

High over the right bank of Ledbetter Creek, 2,000 feet northeast of Location No. 31, an adit was started in talus material by a Mr. Lunsford of Nantahala. Talc fragments were found in the debris, but loose ground and inadequate equipment made extensive work impractical.

LOCATION NO. 33

On the northwest contact of the Murphy marble, 1,200 feet northwest of Nantahala Station, a great deal of digging and tunnelling has been done in a talcose, serpentinized schist, apparently outside of the marble formation. Nearly all of the holes are now caved and covered with debris.

LOCATION NO. 34

This prospect, also worked by Mr. Lunsford, seems to be within the marble formation, but talus material is quite deep. Adjacent outcrops of marble are impure, showing large quantities of chlorite, quartz, and micaceous material. Mr. Lunsford is supposed to have sunk a shaft by himself and taken out some talc, but the prospect is now abandoned.

LOCATION NO. 35

The Nantahala Talc and Limestone Company has done core drilling in a draw behind Hewitt Church. The first hole was located over the Nottely quartzite and was abandoned when true conditions were made known; six holes were drilled in the marble formation but incomplete core recovery did not allow a good picture of local conditions. It is believed that the talc-bearing zone of the marble was intercepted in at least three of the six holes, but only a few odd fragments of talc were recovered. Principal variation from a normal sequence of marble zones was in a wide distribution of chlorite and pink marble bands. Otherwise, the sequence of blue, gray, mottled, white, and mixed and slaty marble was satisfactory.

About 100 feet north of the drill holes, and on the nose of a small ridge, an adit goes back into the hill for about 70 feet, obliquely crossing the strike. It is reported that several pockets of talc were encountered in the opening and some talc may be seen on the old dumps.

LOCATION NO. 36

Immediately behind Hewitt School, on a flat area just north of the Southern Railway, considerable talc has been extracted from open pits and shallow adits. Recently one core hole was drilled at this location, but core recovery was entirely unsatisfactory. The discussion of Location No. 37, below, applies in part to this locality.

LOCATIONS NO. 37 & 38

Number 37 indicates the old Hewitt Shaft on the flood plain of Nantahala River. Number 38 indicates the extensive workings on the face of Talc Mountain. Original operations at Locations 36, 37, and 38 were separately carried on by the Nantahala Talc and Marble Company and the North Carolina Talc and Mining Company. The dividing line between holdings is not known, but at any rate, all operations were soon brought together as a single property. Operational records of the property have long since been lost, but it is certain that many thousands of tons of talc have been produced from the combined properties, mostly from the openings on the foreslope of Talc Mountain. Very few of the openings are now accessible. Attempts were made to reconstruct a map of the operations by consulting the many surviving people who were more or less intimate with the work, but descriptions were so conflicting as to be valueless. If mining is revived at any of the locations, it would be wise to ignore completely any information about the older openings and work out all problems anew.

On Talc Mountain successive lenses of fine talc were found and mined, and the zone became a legend in the history of talc production because of the wealth produced. The old workings can be traced down Talc Mountain for nearly 1,000 feet, but can be entered at few places because of caving. A gravity tram was constructed along the face of the mountain. At intervals adits were driven in to intersect the lenses and facili-

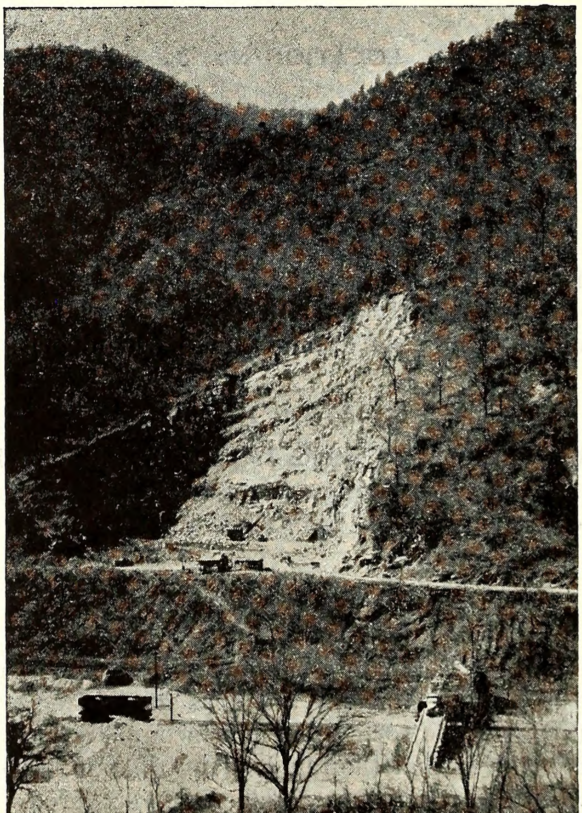


FIG. 10.—MARBLE QUARRY OF THE NANTAHALA TALC AND LIMESTONE COMPANY AT HEWITT. LOOKING NORTHWEST.

tate removal of the great blocks of talc. The front of Talc Mountain has a slope of about 38°, and the average dip of the talc was about 54°, with a plunge of 15°-30° in a southwesterly direction. Thin seams of talc led from lense to lense and there was no drainage problem for the operator. The lower edges of the lower lenses seemed to pinch out about 50 feet above the river, and a fortune was spent searching for a continuation. Finally, talc was discovered in a well at about 10 feet below the level of Nantahala River. A shaft (Location No. 37) was sunk to intercept the lense, ultimately going down to about 80 feet below the river. Here again was disclosed lense after lense of fine talc, though withsuch a decided plunge to the southwest that the lowest drifts were more than 100 feet below the river. After 10 or 12 years of operation in the new mine the water finally proved too much in spite of 16 pumps, powered by water wheel and steam, working day and night, and the mine was abandoned. Modern electric pumps, combined with systematic grouting, might now be able to overcome the water problem, but at that time no electric power was available.[1]

There is no organized production at the present time, but from 60 to 200 pounds of talc per day come in from "scavenger" operations on Talc Mountain, and a few tons of talc were found in pockets in the Hewitt marble quarry several years ago. Several core holes were drilled in front of the Hewitt quarry in 1946 to explore for additional talc, but the data furnished by the cores were of little value.

LOCATION NO. 39

It is reported that some talc was found in Blowing Spring when U. S. Highway 19 was being rebuilt in 1938, but these reports were not verified.

LOCATIONS NO. 40 & 41

These diggings were made in search of talc by Mr. Jim Bailey, of the Silvermine Community, but only fragments of talc-like sericite could be seen by the writer.

PROSPECTING FOR TALC

LOCATIONS FOR PROSPECTING

A general approach to the selection of locations for talc prospecting would be to eliminate those areas where talc could not reasonably be expected, and then to choose from the remaining areas those localities which offer the best probability of success. It must be reasonably certain that the Murphy marble underlies those sites which are being considered. In this respect, comparison should be made with the geologic maps accompanying this report, and a final check should be made in the field.

Specific locations for prospecting cannot be recommended here, other than in the form of data already presented, but it would be well to review some of the relationships which will control the choice of any specific locality.

The prospector must realize that only in comparatively flat topography does the marble lie along a straight outcrop or "strike line." For example, on Sheet 4 of the geologic map it will be seen that the marble has an extraordinarily sinuous outcrop in the rugged topography near the Nantahala River. Such irregularities are caused more by differences in the altitude of the ground surface than by differences in strike and dip. The reason for these irregularities can be visualized if one inclines a sheet of cardboard at 45 degrees (to represent a dipping bed) and proceeds to scissor strips from the two upper corners (to represent changes in elevation, as in two draws on either side of a ridge) ; it will be found that the trimmed edges migrate horizontally in the direction of dip. Topographic effects cannot be overemphasized, as one of the largest known talc bodies of the area was missed by two separate drilling programs because a "strike line" was followed without considering variations of surface elevation.

The more cautious prospectors probably will avoid those places where the marble outcrop is exceptionally narrow, or those areas where the marble outcrop is unusually wide because of repetition by folding, unless there is available such definite information as exposures of talc or silicified marble, or stratigraphic data supplied by water wells, excavations, or previous core drilling.

[1] From a summary prepared by Mr. E. L. Miller, Jr.

Ordinarily, choice should not be made of sites in or near rivers, large creeks, swamps, or other places where water hazards are great at the start. It is well also to consider any interference that might result from the positions of railroads, highways, or other public and private developments. The finding of talc is of no consequence if the talc cannot be removed economically.

METHODS OF PROSPECTING

Residual or transported deposits of clay-stained talc might best be prospected by means of pits, trenches, and auger holes, but these types of deposits probably would be exploited and beneficiated only in conjunction with an established primary talc operation. At the present time, clay-stained talc is not "commercial" in the Murphy marble belt.

The most reliable and economical way to prospect for primary talc, as for similar types of concealed mineral deposits, is by diamond core drilling. It is essential that drilling operations be in the hands of a competent, reputable drilling organization or crew, for it is not merely the drilling of a hole which tells the story, but it is the recovery and interpretation of complete and accurate information furnished by the material which comes from the hole, and by the action of the drill while recovering that material. With modern equipment, methods, and skill, a 10 per cent core loss (discounting open cavities) is excessive and unsatisfactory in the Murphy marble. The modern core drill is a sensitive precision tool which requires skillful operation and control.

When the prospect site has been chosen, and the drilling equipment and crew assembled, an initial hole location must be determined. In general, this step is not so difficult as it may first appear; although work is directed toward the finding of a restricted talc body, the preliminary target is a zone of white, possibly talc-bearing marble which may be as much as 40 feet thick. This white zone is identified by the sequence of blue, gray, and mottled marble which is associated with it.

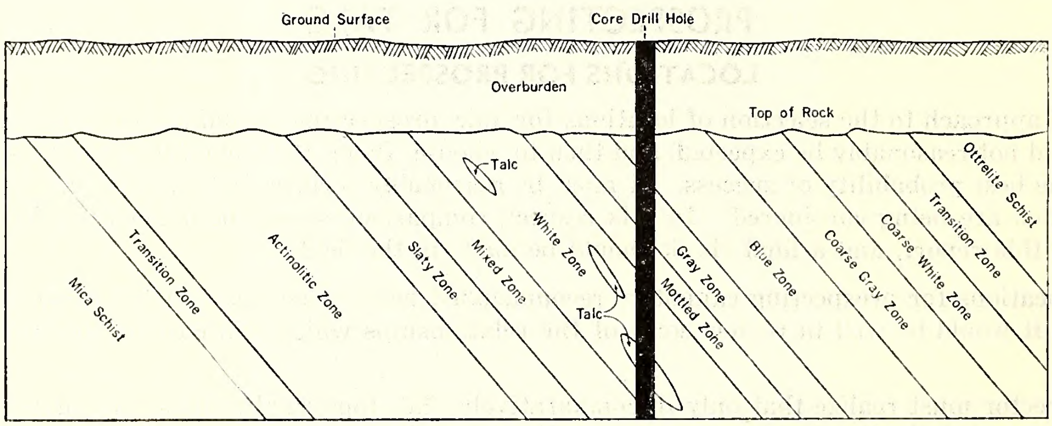


FIG. 11.—DIAGRAMMATIC SECTION SHOWING IDEAL LOCATION OF EXPLORATORY DRILL HOLE.

Figure 11 is a diagrammatic cross section of the marble showing the ideal location of an initial exploration hole. The stratigraphic base (southeast contact in the usual overturned position) of the marble is at the right. The drill hole is located approximately one-third the distance across the marble (northwest) in order to obtain a good stratigraphic section of the blue, gray, mottled, and white marble sequence below top of bed rock. Once the position of the central white marble zone has been established, additional hole locations will depend upon previous results, and some drilling footage may be conserved by including less of the barren section in subsequent holes. It is essential, however, that the white marble zone be encountered below top of bed rock in order that complete core recovery may be obtained in the critical horizon. Although talc deposits conceivably can continue with increased depth inside the white zone, there is an economic limit to depths of preliminary exploration holes, and offsets across the strike to intercept the white marble zone at great depths will be limited accordingly.

In the event that talc is intercepted, particular attention must be given to the manner in which axes of plunging talc bodies vary from the strike of the enclosing marble beds. For example, assume that the marble strikes N45°E and dips 45°SE. If the fold axes plunge 45° from the horizontal, the talc bodies will plunge 45° also, in a direction straight down the dip to the southeast; if the plunge is 30°, the talc bodies will plunge 30° in a direction more nearly south; if the fold axes have no plunge, the talc bodies also will have no plunge and will be aligned exactly parallel to the strike of the marble. Comparable conditions would exist if the plunge were in a northeasterly direction.

Figure 12 is a diagrammatic plan taken at some elevation below top of rock. The blue, gray, mottled, white, and mixed marble zones strike N45°E and dip 45°SE. Various talc bodies, which plunge 22° southeast, are projected up or down to the horizontal plane at which the view is taken. All of the talc bodies are contained within the white zone which dips beneath the mottled, gray, and blue zones. Under these particular conditions, the talc bodies are aligned at an angle of about 25° with the strike of the marble. As core drilling progresses along the strike, holes No. 1 and No. 2 are barren, but hole No. 3 encounters talc; a knowledge of the local geology indicates that the line of drilling should be changed to confirm with the probable axis of the

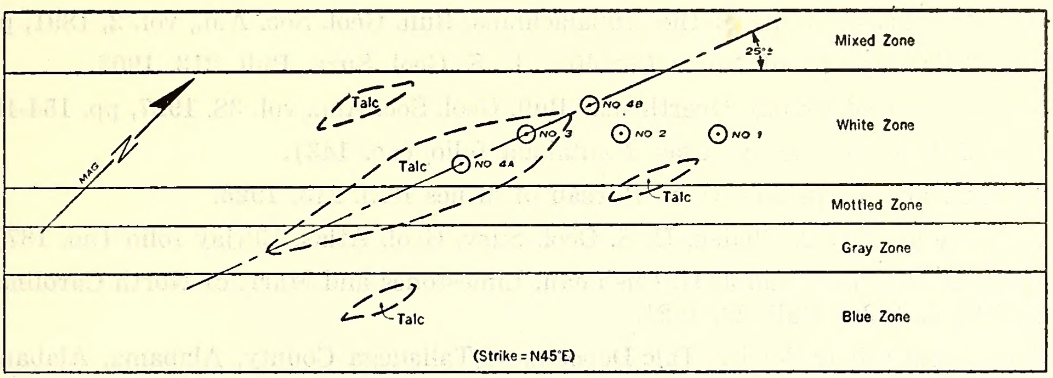


FIG. 12.—DIAGRAMMATIC PLAN DETAIL OF ORIENTATION OF TALC BODIES AND DRILLING CONTROL. PLAN IS TAKEN AT AN ELEVATION BELOW TOP OF ROCK. NOTE. TALC BODIES ARE CONTAINED ENTIRELY WITHIN THE WHITE ZONE AND PLUNGE BENEATH THE MOTTLED, GRAY, AND BLUE ZONES.

talc body, and hole No. 4a is drilled down the plunge. If this hole had been barren, the next choice would have been a location in the opposite direction, up the plunge. Finally, once talc is discovered, the body should be completely delimited before any thought is given to the sinking of a shaft.

The foregoing discussions are intended to be explanatory rather than categorical. Exploration for concealed deposits does not comprise the mechanical application of "cookbook" rules and methods; to the contrary, a maximum of technical knowledge, resourcefulness, and intuition is required if any measure of success is to be achieved. As regards technical knowledge, if the data submitted here are to be used to any advantage, it is essential that geological control be exercised in all phases of talc exploration. Drill holes must be located to best advantage and cores must be adequately logged and interpreted for maximum utilization of "dry" holes. Geologic sections and subsurface plans should be prepared. In addition, the competent geologist, by means of intuition developed through experience, often can predict a little beyond tangible data. Much of these types of assistance is available from various public agencies and full advantage should be taken of them. In the event that some time must elapse between the gathering of information and the examination of the data by competent authorities, it is especially needful that all data and material be kept in as perfect condition as possible. It never hurts even to carry the most minute precautions almost to an extreme.

One final word applies to all forms of mining ventures. It is never wise to risk more than one can afford to lose.

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